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Evaluation of Fuel Wood Properties of *Melia dubia* at Different Age Gradation

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Abstract

Study was carried out at Forest College and Research Institute, Mettupalayam, Tamil Nadu, India using different age gradation viz., one, two, three, four and five year of Melia dubia wood samples collected from the plantations raised at Kollegal, Samraj Nagar District, Karnataka to evaluate the fuel wood properties. Among the different age gradation of Melia dubia 5-year age old wood recorded high calorific value (3820.00 Kcal Kg^{-1}) and high Fuel wood Value Index (4125.60). The proximate analysis of 5-year age old Melia dubia recorded lowest value for moisture content (8.00 %); volatile matter (66.50 %) and ash content (0.50 %) and highest fixed carbon content (25.00 %). In a holistic perspective, the study identified that the 5-year age-old Melia dubia wood exhibited superiority in all energy properties that lend support to its amenability for energy utility.

Keywords: Fuel wood, calorific value, fuel wood value index, ash fusion temperature, fixed carbon content.

Introduction

The uses of wood as fuel is traditional one and continue as the most important universal fuel for rural areas of developing countries and the demand will increase enormously in the future, as the underground fuels become expensive[1]. Wood is renewable and its production can be sustained which is the most accessible and cheapest source of energy for most of the rural people[2]. The consumption of fuel wood is one of the most significant reasons for forest loss in many countries, and the estimates indicate that fuel wood accounts for over 54% of the total global harvest per annum[3]. The fuel wood demand in the country ranges from 96 to 157 million tonnes annually, including a rural demand of 80–128 million tonnes, thus raising the consumption level to 148–242 kg per capita[4]. Acute shortage of fuel wood and the resultant higher price leads to the burning of more than 80 to 100 million tonnes of dry cow-dung cakes annually, representing 400 to 500 million tonnes of wet dung, which could increase our agricultural production substantially. The annual fuel wood consumption of the country is 216.42 million tonnes out of which 58.75m tones come from forests. Of the total population using fuel wood, 23 per cent population is obtaining fuel wood from the forests[5].

About half the world's population cook with biomass fuels which provide around 35 per cent of energy supplies in the developing countries. Natural resource management depends on fuel wood collection and consumption pattern[6]. There is a two-way relationship between fuel wood collection and deforestation. Forest degradation, on the other hand, leads to a situation of fuel wood scarcity. In addition, there are a number of other adverse consequences of forest degradation, including loss of biodiversity, deterioration of watershed management functions, release of carbon dioxide into the atmosphere, and soil erosion. Alternate source of rural domestic energy such as crop residues, animal dung, wood from energy plantations on the farmlands and biogas do not cause forest degradation. These alternative fuel wood sources can reduce pressure on natural forests by introducing fast growing short rotation indigenous species. Various fast growing tree species amenable for energy plantations are very well documented[7]. Recently many biomass companies are promoting *Melia dubia* (Malabar neem) as an efficient source of energy without characterizing their energy properties[8]. Taxonomically this species belongs to the order Meliales; family: Meliaceae; sub-family: Meliodeae. It is a large, handsome deciduous and fast growing tree up to 20-25 m height and 1.2-1.5 m in girth, with straight cylindrical bole of about 9-12 m. The tree is leafless for a short period from December to February and the new leaves appear in February to March. The flower appears in April and soon after replaced by bunches of ovoid drupes, which ripens in the cold season from October to February. It believed that *Melia dubia* originated in India. However, the exact origin is uncertain. Outside India, it found in Sri Lanka, Malaysia, Java, China and Australia. Due to its wide distribution, the tree is capable of withstanding wide range of climatic conditions. The tree is cultivated in the arid and semi-arid region, also in the semi- moist areas. The energy value and energy characterization of this species are not available for industrial use and this warrants adequate research in this species in order to characterize the energy value of this species at various age gradation against this backdrop, the current study evaluated the fuel wood properties of *Melia dubia* from 1-year to 5-year age-old plantations.

Material and Methods

Sample collection: Randomly selected wood samples of *Melia dubia* was collected from the plantations raised at different age gradation *viz.*, one, two, three, four and five year age old located at Kollegal, Samraj Nagar District, Karnataka at 12˚04'N latitude and 77˚09'E longitude during September, 2010. These divided into four replicates of 10 cm length. Samples were air dried and made into powder and used for various analyses.

Wood Density: The basic density of each wood sample was finding out by using the displacement method[9] and the density were calculated using the formula.

$$\text{Basic Density} = \frac{E_2}{F + G}$$

Where, E_2- Green weight (after soaking in water for 48 hours), F – Oven dry weight, G – Deflection of the needle in cm due to water displacement.

Chemical Analysis: The moisture content plays an important role in determining the energy properties of any wood. Moisture content was determined by weighing the sample before and after drying in electrical hot air oven at 103 ± 5^0C for one hour[10]. The difference in weight before and after drying indicated the moisture content of each sample. The moisture content is determined as follows.

$$\text{Moisture Content}(\%) = \frac{(\text{Wet weight} - \text{Dry weight})}{\text{Wet weight}} \times 100$$

The percentage of volatile matter was determined based on ASTM Standard E711-87[11]. For percentage of volatile matter, one gram of biomass sample was placed in a crucible of known weight and oven dried to constant weight after which it was heated in the furnace at temperature of 600^0 C for 10 minutes. The per cent of ash content followed the same procedure with volatile matter except the same sample was heated in the furnace for 3 hours[12]. The fixed carbon content was found out by subtracting the sum of percentage of ash content and percentage of volatile matter from 100. The fixed carbon calculated according to C = 100 (V + A), where as C – Percentage of fixed carbon, V–percentage of volatile matter and A –percentage of ash.

Thermal Properties: Calorific Value: The calorific value of dried powdered wood samples was determined with a bomb calorimeter, in which about 0.5 g of oven-dried wood was completely combusted under a pressure of 425 psi with pure oxygen, and the rise in temperature of the cylinder allows the calculation of the calorific value when the exact weight of the sample known. The bomb calorimeter calibrated against benzoic acid standards before the analysis of samples[13].

Ash Deformation Temperature and Ash Fusion Temperature: The deformation and fusion temperature of ash was checked using muffle furnace. In the present study, the ash of *Melia dubia* at different age gradation was used to check their deformation and fusion temperature. The ash was made to cone and kept in muffle furnace and fusion temperature was checked[14].

Fuel wood value index (FVI): Fuel wood value index is calculated based on the properties of calorific value, wood density and ash content[15].

$$\text{Fuel wood Value Index} = \frac{(\text{Calorific value} - \text{Wood density})}{\text{Ash content } (\%)}$$

Results and Discussion

Wood density: The physical characteristics, bulk and basic density played an important role in biomass energy. In the current study highest wood density was observed in 5-year age old *Melia dubia* (500.20 kg m^{-3}) and lowest in 1-year age old (418.30 kg m^{-3}). While 5-year age old was significantly higher than the general mean (463.26 kg m^{-3}), all other age gradation recorded non-significant lower values depicted in table 1.The current study showed that wood density of *Melia dubia* increases with the age, which in turn increases the fuel wood value index (FVI). An ideal fuel wood species should have high calorific value coupled with high wood density and low ash content[5].

Chemical Analysis: Proximate analysis includes moisture content, volatile matter content, ash content and the fixed carbon content. Among the different age gradation, 5-year age-old wood had the lower moisture content of 8.00 per cent and 1-year age-old wood sample had higher moisture content of 11.75 per cent. Moisture content differed significantly among different age gradation. The current study established that the moisture content of wood decreases with increase in age of the tree. Thus decrease in moisture content increases the fuel value of the wood. Moisture in wood generally decreases its caloric value, which established by a number of investigators[16]. The heartwood moisture content is lower than sapwood, as moisture content falls during the transformation of sapwood to heartwood[17].

Volatile matter content of the different age gradation of *Melia dubia* ranged between 69.00 per cent (1-year) and 66.50 per cent (5-year). The volatile matter was not significant between different age gradation. The present study found that the volatile matter of *Melia dubia* wood decreases with increase in tree age.

The value of ash content of the different age gradation ranged from 1.00 to 0.50 per cent. The maximum ash content value of 1.00 per cent reported for 1-year age-old wood and it is significantly higher than the general does mean (0.75 per cent). This result showed that ash content of *Melia dubia* wood decreases with increase in tree age. Tree age had apparent influence on ash content. High wood ash content is less desirable for fuel, as it is noncombustible, and reduces the heat of combustion. The current study was in concurrence with Goel and Behl[18], for ash content in *Acacia auriculiformis*, *Acacia nilotica*, *Prosopis juliflora* and *Terminalia arjuna* at different age gradation. Species like *Litsea assamica*, *Chuckrasia. tabularis*, *Cinnamomom tamala*, *Cinnamomom caudatum*, *Indigofera tinctoria* and these species also considered as good fuel wood on account of comparatively low ash content[19].

Table-1
Physical, chemical and thermal characteristics of *Melia dubia* at different age gradation

Age in Years	Basic density (OD basis) (kg /m^3)	Moisture Content (%)	Volatile Matter (%)	Ash Content (%)	Fixed Carbon (%)	Calorific Value (Kcal/Kg)	Fuel Value Index	Ash Deformation Temperature (°C)	Ash fusion Temperature (°C)
1	418.30	11.75	69.00	1.00	18.25	3461.00	1540.15	1023.33	1083.33
2	443.50	11.00	68.50	0.87	19.63	3516.00	1859.03	1066.67	1136.67
3	468.70	9.25	68.25	0.75	21.75	3612.67	2288.02	1120.00	1170.00
4	485.60	8.65	67.35	0.63	23.37	3716.67	2949.74	1153.33	1200.00
5	500.20	8.00	66.50	0.50	25.00	3820.00	4125.60	1200.00	1250.00
Mean	463.26	9.73	67.92	0.75	21.60	3625.27	2552.51	1112.67	1168.00
SEd	10.74	0.24	0.88	0.06	0.56	62.16	59.04	17.51	25.99
CD(0.05)	23.92	0.53	NS	0.14	1.25	138.49	131.55	39.02	57.91

The value of fixed carbon content at different age gradation varied between 18.25 per cent (1-year age old) and 25.00 per cent (5-year age-old) presented in table 1. The result registered that the fixed carbon content increases with increase in the age of the tree. Goel and Bhel[18] reported similar trend for total carbon content in *Acacia auriculiformis*, *Acacia nilotica*, *Prosopis juliflora* and *Terminalia arjuna* at different age gradation which lend support to the current findings in *Melia dubia.*

Thermal Characteristics: The quality of fuel wood depends on qualitative and quantitative properties of wood. Quantitative properties include calorific value, density, moisture content, ash, silica content, drying rate and chemical composition. The higher the moisture content, the less efficient is the wood as a fuel since the net calorific value reduced. Moreover, it recorded that the moisture content of wood varies with the dimensions of branches, season of the year and so on. Thus, water content cannot be considered as part of the intrinsic value of a species as a fuel since it can vary. The selection of ideal fuel wood species based on its FVI, calculated using calorific value, wood density and ash content[13].

Calorific Value: In general, an ideal fuel wood species should have high calorific value, high density, and low ash content. Earlier researchers have reported that tropical species had comparatively higher ash and water content than temperate species. The calorific values of *Melia dubia* wood increased with the increase in the age of the tree. The highest was 3820.00 Kcal/Kg for 5-year age-old wood sample and the lowest value was 3461.00 Kcal/Kg for 1-year age-old wood. Similar result recorded by Goel and Behl[18] in *Acacia auriculiformis*, *Acacia nilotica*, *Prosopis juliflora* and *Terminalia arjuna* at 5, 10 and 15 year age old wood samples indicating that calorific value increases with the age of the tree. The present findings are in agreement with those reported by earlier workers[10,13,15].

Fuel wood Value Index (FVI): The fuel wood value index of *Melia dubia* ranged from 1540.15 (1-year age old) to 4125.60 (5-year age old). The results showed that 5-year age old wood sample recorded significantly higher **(FVI)** compared to the average value followed by 4-year age old wood sample presented in table 1. The result registered that fuel wood value index increases with increase in age of the tree which was due to increase in calorific value and wood density along with tree age and also due the decrease in ash content with increase in tree age. A combination of three factors: calorific value, density, and ash content, will be most appropriate in determining the suitability of a wood as fuel. On this basis, of the 26 species analyzed, *B. nitida* has the highest FVI, followed by *Machilus bombycina*, *Itea macrophylla*, *Cryptomeria japonica*, *G. arborea*, *S. populnea*, *M. denticulata* and *S. wallichii*[19]. The FVI is an important characteristic for screening desirable fuel wood species[15, 20] and hence higher FVI value recorded in 5-year age-old wood sample in the current study indicated its amenability towards various energy purposes.

Ash Fusion and Deformation Temperature: Ash fusion and ash deformation temperature are difficult to determine exactly, hence it expressed in the range. Ash deformation temperature was less than ash fusion temperature. The difference of temperature in between these two is up to a maximum of 50°C.The temperature in the oxidation zone can vary between 1200 and 1400°C and hence most of the wood residue ash can fuse in this zone. In the present study on *Melia dubia* wood, ash deformation temperature ranged from 1023.33°C to 1200.00°C shown in table 1. This result showed that ash deformation temperature increases with the increase in age of the tree which showed that the fuel wood quality of this species improves with the age of tree. The ash fusion temperature for different age gradation of *Melia dubia* was minimum in 1-year old wood sample (1083.33°C) and maximum in 5-year age old wood sample (1250.00°C) (table 1). The 5-year age old wood ash fusion temperature was significantly different from 3, 2 and 1-year age old wood sample values. The present study established that ash fusion temperature of *Melia dubia* wood increases with the increase in age of the tree. The high ash fusion temperature reduces the maintenance of industrial boilers. This showed that *Melia dubia* had higher ash fusion temperature than other biomass fuels so it is highly suitable for biomass based industries. Similarly the ash fusion temperature was in the range of 1100-1200°C and the ash deformation temperature found less than ash fusion temperature by 50-100°C for briquettes made of combination of cotton plus soybean stalks[21].

Conclusion

In a holistic perspective, the result of the current study apparently indicates that *M. dubia* is amenable for biomass based power generation industries due to their ideal energy value. The analysis of *M. dubia* wood at five different ages indicated that 5-year age is amenable to utilize as fuel wood due to their superiority in physical, chemical and thermal properties and recommends 5-year rotation for energy purpose. The productivity also indicated that *M. dubia* is fast growing tree with the growth rate of 41.54 m^3/ha/yr coupled with multifarious utility which extended greater scope of its utility for various wood based industry.

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