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Fuel wood properties of some oak tree species of Manipur, India

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Abstract

Five indigenous oak tree species i.e., *Castanopsis indica* (Roxb. ex Lindl.) A.DC., *Lithocarpus fenestratus* (Roxb.) Rehder, *Lithocarpus pachyphyllus* (Kurz) Rehder, *Lithocarpus polystachyus* (Wall. ex A.DC.) Rehder and *Quercus serrata* Murray were estimated for their wood properties such as calorific value, density, moisture content and ash content from a sub-tropical forest of Haraothel hill, Senapati District, Manipur. Wood biomass components were found to have higher calorific value (kJ g^{-1}) than bark components. The calorific values for tree species were found highest in *L. pachyphyllus* (17.99 kJ g^{-1}) followed by *C. indica* (17.98 kJ g^{-1}), *L. fenestratus* (17.96 kJ g^{-1}), *L. polystachyus* (17.80 kJ g^{-1}) and *Q. serrata* (17.49 kJ g^{-1}). Calorific values for bole bark, bole wood and branch bark were found significantly different ($F > 3.48$ at $p = 0.05$) in five oak tree species. Percentage of ash on dry weight basis was found to be highest in *Q. serrata* (4.73%) and lowest in *C. indica* (2.19%). Ash content of tree components gives a singnificant factor in determining fuelwood value index (FVI). Of all the five oak tree species, *Q. serrata* exhibited highest value of wood density (0.78 g cm^{-3}) and lowest was observed in *C. indica* (0.63 g cm^{-3}). There was significant correlation between wood density ($p<0.05$), ash content ($p<0.01$) with calorific value in oak tree species. Fuelwood value index (FVI) was in the following order: *C. indica* (1109.70) > *L. pachyphyllus* (898.41) > *L. polystachyus* (879.02) > *L. fenestratus* (824.61) > *Q. serrata* (792.50). Thus, the present study suggests that *C. indica* may be considered as a fuelwood oak tree species in Manipur.

Key words

Calorific value, Fuelwood value index, Oak species, Manipur

Introduction

Forest plays an important role in providing fuelwood in many developing countries. However, in order to understand the use of forest products for fuelwood, proper knowledge of fuelwood quality of tree species is highly needed. Fuelwood is the fourth largest source of energy used for meeting 80% of the cooking energy in India (Jain and Singh, 1999). In hilly regions, people are mainly dependent on forest products for their daily necessities of life. As per the results of the Household Consumer Expenditure Survey (NSSO, 2007-08) in rural India, over 77.6 and in urban India 20.1 % of households in the country depend on fuelwood and chips (NSSO, 2007-08). Therefore, there is severe imbalance between demand and supply for fuelwood at a localized scale resulting in progressive deforestation. Calorific value is the most important parameter for deciding and comparing the effectiveness of any fuel. The ranking of fuelwood quality based on Fuelwood Value Index (FVI) was reported by Deka *et al.* (2007). In North-East India, there are large number of indigenous tree species for its high potentiality and diversity of climate, topography and soil. The main objective of the present study was to investigate the calorific value (kJ g^{-1}), wood density (g cm^{-3}), ash content (%) and moisture content (%) for fuelwood components (bole, branch and twig) of five oak species.

Materials and Methods

Wood and bark components of five oak tree species *C. indica, L. fenestratus, L. pachyphyllus, L. polystachyus* and *Q. serrata* were collected by harvesting them during peak growth period of November 2009, with three trees of each species from Haraothel hill, a sub tropical broad-leaved forest of Manipur above 935 m from mean sea level. Bark and wood components were collected species-wise in polythene bags to avoid moisture loss and brought to laboratory. Known amount of bark and wood samples were separately oven dried at 80 ºC to determine the moisture content. Oven dry samples of different plant components (bole, branch and twigs) of five oak tree species were ground and 1g composite of powdered sample was pelleted to burn in Bomb Calorimeter to determine the calorific content. Density was determined by water displacement method (weight loss of the cut discs under glycerine or water) as per ASTM-D 2395-93 (1995). Ash content was determined by burning of 1g of powdered sample in a Muffle furnace at 575 ºC for 4 hrs. Statistical mean and standard deviation were calculated by MS Excel 2007 and ANOVA was calculated by using SPSS v.20. Fuelwood Value Index (FVI) of each tree species was calculated by the method of Goel and Behl (1996).

Results and Discussion

The bole bark components in *L. polystachyus* exhibited highest calorific value (18.33 ± 0.05 kJ g^{-1}) and lowest was observed in *Q. serrata* (17.31 ± 0.17 kJ g^{-1}). The highest value of bole wood was recorded to be 19.06 ± 0.57 kJ g^{-1} in *L. pachyphyllus* and lowest was 17.98 ± 0.13 kJ g^{-1}in *Q. serrata*. Of all the branch barks, highest calorific value was found in *L. fenestratus* (18.02 ± 0.20 kJ g^{-1}) and lowest in *Q. serrata* (17.16 ± 0.07 kJ g^{-1}). Calorific values of branch woods of five oak tree species were in the order of: *C. indica* (18.35 ± 0.45 kJ g^{-1}) > *L. pachyphyllus* (18.17 ± 0.56 kJ g^{-1}) > *L. fenestratus* (18.09 ± 0.28 kJ g^{-1}) > *L. polystachyus* (17.87 ± 0.18 kJ g^{-1}) > *Q. serrata* (17.83 ± 0.36 kJ g^{-1}). Out of the five oak tree species, highest calorific value in twig bark was evident in *L. pachyphyllus* (17.61 ± 0.29 kJ g^{-1}) followed by *C. indica* (17.57 ± 0.22 kJ g^{-1}), *L. fenestratus* (17.27 ± 0.23 kJ g^{-1}), *L. polystachyus* (17.20 ± 0.21 kJ g^{-1}) and lowest in *Q. serrata* (17.05 ± 0.23 kJ g^{-1}). Of all twig woods of oak tree species, highest calorific value was recorded as 17.72 ± 0.26 kJ g^{-1}in *L. fenestratus* and 17.68±0.40 kJ g^{-1} in *L. pachyphyllus* and lowest of 17.53±0.06 kJ g^{-1}in *C. indica* (Table 1).

Calorific values were in the range of 17-19 kJ g^{-1} in all the five oak tree species. Among the tree components, bole and branch portions are mainly used as fuel. Calorific values of the components were found to be high and similar findings were reported by Kataki and Konwer (2001, 2002). High calorific values may be due to high concentration of extractives and lignins in wood (Kataki and Konwer, 2001; Demirbas and Demirbas, 2009). However, high content of dichloromethane extractives promote higher calorific values of tree species in addition to the presence of extractives and lignin (Moya and Tenorio, 2013). Bark components showed lower calorific values as compared to wood components. Similar findings were reported by Senelwa and Sims (1999) and Shavanas and Kumar (2003). Calorific values for bole bark, bole wood and branch bark components were found significantly different (F > 3.48 at p = 0.05) and the calorific values for branch wood, twig bark and twig wood were insignificant. With regard to tissue types, calorific values of bark component were generally lower than that of wood samples due to their higher percentage of ash content. Of all the five oak tree species, *L. pachyphyllus* exhibited highest calorific values (17.99 ± 0.57 kJ g^{-1}) followed by *C. indica* (17.98 ± 0.44 kJ g^{-1}), *L. fenestratus* (17.96 ± 0.45 kJ g^{-1}) *L. polystachyus* (17.80 ± 0.52 kJ g^{-1}) and the lowest calorific values were observed in *Q. serrata* (17.49 ± 0.38 kJ g^{-1}). Low calorific value in *Q. serrata* may be due to the presence of higher ash content than the other oak species. Specific gravity or wood density of tree species also play an important role in determining the quslity of fuelwood. In the present study, highest wood density was observed in *Q. serrata* (0.78 ± 0.06 g cm^{-3}), followed by *L. polystachyus* (0.76 ± 0.10 g cm^{-3}), *L. pachyphyllus* (0.75 ± 0.08 g cm^{-3}) and *L. fenestratus* (0.72 ± 0.06 g cm^{-3}). Lowest wood density was noticed in *C. indica* (0.63 ± 0.10 g cm^{-3}) [Table 2]. The density of wood also determines a positive factor in fuelwood quality due to its durability on heating. Wood density of five oak tree species showed a significant positive correlation (p<0.05) with the calorific values of wood samples. However, moisture content was negatively correlated but was not significant with the calorific values (Table 3). High wood density found in *Q. serrata* may be due to high lignification. Presence of lignin and other denser fractions or complex wood ultrastructure, apparently enhances wood density, reiterating strong link

Table 1 : Calorific values of biomass components for five oak tree species of Manipur, India

	Calorific values (kJ g^{-1})					
	Bark			Wood		
	Bole bark	**Branch bark**	**Twig bark**	**Bole wood**	**Branch wood**	**Twig wood**
Species	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Castanopsis indica	18.28 ± 0.23	17.65 ± 0.36	17.57 ± 0.22	18.50 ± 0.39	18.35 ± 0.45	17.53 ± 0.06
Lithocarpus fenestratus	17.98 ± 0.06	18.02 ± 0.20	17.27 ± 0.23	18.65 ± 0.06	18.09 ± 0.28	17.72 ± 0.26
Lithocarpus pachyphyllus	17.87 ± 0.28	17.57 ± 0.30	17.61 ± 0.29	19.06 ± 0.57	18.17 ± 0.56	17.68 ± 0.40
Lithocarpus polystachyus	18.33 ± 0.05	17.31 ± 0.34	17.20 ± 0.21	18.45 ± 0.27	17.87 ± 0.18	17.61 ± 0.36
Quercus serrata	17.31 ± 0.17	17.16 ± 0.07	17.05 ± 0.23	17.98 ± 0.13	17.83 ± 0.36	17.61 ± 0.13
Mean	17.95 ± 0.16	17.54 ± 0.25	17.34 ± 0.24	18.53 ± 0.29	18.06 ± 0.37	17.63 ± 0.24

Least significant difference for comparing tissue types (p<0.05) = 0.48; Least significant difference for comparing species × tissue type interaction (p<0.05) =0.82

Table 2 : Fuelwood characteristics for five oak tree species of Manipur, India

Tree species	Calorific value (kJ g^{-1})	Density (g cm^{-3})	Moisture content (%)	Ash content (%)	FVI
Castanopsis indica	17.98 ± 0.44	0.63 ± 0.10	46.61 ± 8.90	2.19 ± 1.21	1109.70
Lithocarpus pachyphyllus	17.99 ± 0.57	0.75 ± 0.08	43.28 ± 7.72	3.47 ± 1.91	898.41
Lithocarpus polystachyus	17.80 ± 0.52	0.76 ± 0.10	42.28 ± 6.72	3.64 ± 1.05	879.02
Lithocarpus fenestratus	17.96 ± 0.45	0.72 ± 0.06	39.50 ± 2.68	3.97 ± 0.59	824.61
Quercus serrata	17.49 ± 0.38	0.78 ± 0.06	36.39 ± 6.56	4.73 ± 2.16	792.58

Table 3 : Correlation (Pearson) between calorific values with density, ash content and moisture content of five oak tree species of Manipur, India

Characteristics	Calorific values	Calorific values between	
		Bark	Wood
Density	0.538*	ND	0.538*
Ash content	-0.592**	-0.488	-0.376
Moisture content	-0.350	0.382	-0.563*

Note: ND= Not Determined, *statistical significant parameter at 0.05 and **statistical significant parameter at 0.01

between chemical constituents of wood and their physical properties (Kumar, 2006).

The value of ash percentage for determining fuelwood quality was highest in *Q. serrata* (4.73±2.16 %) which indicates a negative factor to fuelwood quality. The percentage of ash content was found higher in bark portion than wood portion. Ash percentage in tree components of five oak tree species showed significant difference between bark and wood biomass components. Ash percentage of five oak tree species was found to be negatively correlated and significant with the calorific values ($p<0.01$).Highest ash percentage in *Q. serrata* (4.73 ± 2.16%) may be due to predominant presence of silicon and calcium in the samples (Umamaheshwaran and Batra, 2008; Monti *et al.*, 2011).

Among the five oak tree species studied highest percentage of moisture content was recorded in *C. indica* (46.61 ± 8.90 %) followed by *L. pachyphyllus* (43.28 ± 7.72 %), *L. polystachyus* (42.28 ± 6.72 %), *L. fenestratus* (39.50 ± 2.68 %) and lowest moisture content was observed in *Q. serrata* (36.39 ± 6.56 %). In the present study, *Q. serrata* exhibited high density of wood with low moisture content (Table 2). In the present study among tree components bark portion contained high moisture content than the wood portion.

FVI of five oak tree species was in the order of: *C. indica* (1109.70) > *L. pachyphyllus* (898.41) > *L. polystachyus* (879.02) > *L. fenestratus* (824.61) > *Q. serrata* (792.58). Of all the five oak tree species, highest FVI was recorded in *C. indica* (1109.70) due to lower value of ash content as compared to other species.

In the present investigation, *C. indica* exhibited highest FVI value due to its lowest value of ash content as compared to other species. Therefore, out of five oak tree species, this oak tree may be regarded as the best quality of fuelwood species followed by *L. pachyphyllus*, *L. polystachyus*, *L. fenestratus* and *Q. serrata*. in Manipur, North-East India.

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