Evaluation of Energy Properties of Lesser Known Native Species; Nataw (*Xylopia parviflora*)

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ABSTRACT

The most common forms of biomass available in Sri Lanka are fuel wood. Among fuel woods Hevea brasiliensis (rubber) play major role as firewood to fulfill energy requirements. Especially industries demanded by rubber are not enough to meet the demand of fire wood. In this context, traditional users of fuelwood face difficulties in maintaining a stable supply of fuelwood. Therefore, there is an essential need in identifying possible, potential and high efficient biomass energy source to fulfill energy requirement in the country according to country's energy policy targets.

This study was designed to evaluate energy and mechanical properties of Nataw (Xylopia parviflora) to see its applicability as fuel wood in biomass boilers. To study the fuel wood characteristics of Nataw (Xylopia parviflora), individuals were categorized in to three diameter classes dbh class (5cm -15cm, 15cm - 25cm ,25cm - 35cm). In each individual four samples were taken from a wood disk extracted at breast height (1.3m). Moisture content, density, specific gravity, ash content, volatile matter, fixed carbon and biomass/ash ratio were measured from five individuals from each diameter class. Certain characteristics including moisture content, density, specific gravity, and ash content had no significant difference among three dbh classes. Volatile matter content was significantly higher and fixed carbon content was significantly lower than the other two types of dbh classes in 25cm – 35cm diameter class, the largest diameter class. When compare energy characteristics of Xylopia parviflora with Hevea brasiliensis, moisture content (31.22%) ash content (1.24%) were lower than the rubber. However Calorific values (18.92 kJ/g) and FVI (3055) higher than the rubber concluding Xylopia parviflora could perform better than rubber as a fuel wood in biomass boilers.

Key words: Energy properties, fuel wood, *Xylopia parviflora*, biomass energy

Introduction

Throughout the centuries, energy production has been gradually increasing with the industrialization. Apart from industrialization, increasing energy demand are rapid economic development and population growth can be identified as other diving forces for high energy consumption. Current prediction shows that growing demand will continue to grow. (Poland and energy sector of the world, 2014, Pérez-Lombard et al., 2008, Goldemberg et al., 1988).

Biomass is seen as an interesting source of renewable energy that can be utilized to reduce associated environmental impacts. Like other energy resource there are limitations in the use and applicability of biomass and it must compete not only with fossil fuels but with other renewable energy sources such as wind, solar and wave power (McKendry, 2002, Hoogwijk et al., 2008)

Due to diverse nature of landscape and tropical climatic conditions, Sri Lanka is blessed with several types of renewable energy resources namely biomass, hydro power, solar, and wind. Among them, biomass is the most common source of energy supply in the country and the largest use of biomass is in the domestic sector for cooking purposes (Sri Lanka Sustainable Energy Authority, 2015).

Nearly 72% of industrial boilers in Sri Lanka which use biomass as fuel consumes fuel wood, 15% of paddy husk and saw dust and 13% of coconut shells. As industrial sector in Sri Lanka currently use fuel wood as the major source of biomass energy the demand for field wood on steady rise (Leelarathne, 2016).

Wood fuels consists of woody biomass such as stems, branches, twigs, sawdust and other residues obtain from logging and wood processing activities such as saw-milling, manufacturing of plywood and particle board, as well as charcoal from these sources. The primary sources of wood fuels are obtained from forest and other wood-land consist of natural forests, scrub lands, wood and timber plantations, woodlots and dedicated fuel wood plantations. Non-forest land includes agricultural land, agro-forestry systems, wasteland, line trees, home gardens, etc. (UNDP, 2013). According to UNDP (2013) and Fuelwood Resource Survey of Sri Lanka, (2016) *Hevea brasiliensis, Pariserianthus falcataria, Acacia decurrens, Clusia rosea, Leucaena leucocephala, Calliandra calothyrsus, Eucalyptus grandis, Acacia auriculiformis, Gliricidia sepium, Casurina equisitifolia* species are widely used as fuel wood in Sri Lanka to produce thermal energy in industries. Among fuel woods *Hevea brasiliensis* (rubber) play major role as firewood to fulfil energy requirements. As rubber is used as a timber in furniture manufacturing, brush handles, broom handles and other type of products it is difficult to meet rubber wood demand for industrial boilers. In this context, traditional users of fuel wood face difficulties in maintaining a stable supply

of fuel wood. On the other hand, during the last decades many Rubber lands have been converted to Tea and Palm oil plantation resulting reduction in Rubber cover. (Fuel wood Resource Survey of Sri Lanka, 2016). Therefore, there is an essential need in identifying possible, potential and high efficient biomass energy source and processing mechanism to fulfil energy requirement in the country.

Study Objectives

This study was conducted to identify an ideal native lesser known fuel wood species in Kalutara district, to compare energy characteristics of different diameter classes of identified fuel wood species. As specific objectives, study intended to compare calorific value of identified native fuel wood species with array of widely use fuel wood species in Sri Lanka.

Materials and Methods

Study area and climate

Kalutara district (1598 km^2), Western province was selected as sampling site to conduct the study. Kalutara district is in the wet zone and it is boarded to the North by the Bolgoda river, to the South by the Bentota river, East by the Rathnapura district, West by the Indian Ocean and identifies two third of its land area as a plain, of the total land extent. The main characteristics of the climate are high rainfall, high temperature and high humidity throughout the year. Kalutara is experienced two monsoon periods are experience from May to August (Southwest monsoon) and October to January (Northeast monsoon) (Fuelwood Resource Survey of Sri Lanka, 2016). In Kalutara District, land use consists with many land use types including rubber plantation followed by home gardens, paddy farming and forest. However, Kalutara is the only district which utilized more than 30% of the total land area for rubber plantations of the country. Home gardens also cover nearly 25% of the total land area.

More than of 14% of industries in the Kaluthara area uses biomass boilers to partially fulfil their energy requirements (Sri Lanka Sustainable Energy Authority, 2015). Also these industries face the shortage of biomass supply to run their biomass boilers. At the same time state owned Pinus plantation (400ha) in the Kalutara is being uprooted and planning to re forest with a *Dipterocarpus zeylanicus*

Collection of secondary data

Industrial survey

A questioner survey was conducted to collect information on fuel wood species that are used in industries, reasons for selecting particular fuel wood species, limitations use, and form of fuel wood use. Fifteen industries were selected randomly to conduct the questionnaire survey.

Household survey

A household survey was conducted in Handapangoda area to identify an abundant but not commonly used fuel wood species by the community in the area. The study population is defined as the household level fuel wood consumers that consume fuel wood for some activities such as boiling water, cooking, boiling paddy, small scale ventures etc. 30 households were surveyed.

Evaluate energy potential of Xylopia parvifolia (nataw)

According to the preliminary household survey, *Xylopia parvifolia* was identified as a lesser known but highly abundant plant in Kalutara district. According to observations and information that gathered from local community, the site located in Handapangoda area in Kalutara district was selected as the study site.

Sampling size and sampling procedure.

Xylopia parvifolia individual with dbh >5cm were selected from a purposive sampling method to conduct the study. Diameter at breast height (dbh) of each selected individual were measured using diameter tape. Each dbh was recorded by giving a tree number for each individual. Then they were categorized in to different diameter classes as below (Table 1).

Table 1: Categories of diameter classes

Diameter class category	DBH class (cm)
X	5 - 14.9
Y	15 - 24.9
Z	25 - 34.9

Five trees from each DBH classes were selected following purposive sampling method. All together fifteen trees representing three diameter classes (5-14.9, 15-24.9, 25-34.9 cm) were selected for the current study.

Extraction of specimen samples to estimate energy characteristics

Sample disk with 5cm width at the breast height of the each selected tree was extracted. The disks were packed in air tight polythene bags until taken them to a saw mill. Each disk was processed to obtain cubes (2cm * 2cm* 2cm) and match sticks sized specimens. Different fuel wood properties including moisture content, density, specific gravity, ash content, volatile matter content, fixed carbon content, and biomass/ash ratio were measured using standard methods. Four replicate were prepared for each individuals. All together 20 replicates (4 match sticks/ 4 cubes * each disk from a tree* five trees) from each diameter class were measured for each parameter.

Measurements and calculations

Diameter at breast height (dbh)

Breast height is defined as 4.5 feet or 1.37 m above the forest floor on the uphill side of the tree. (MacDicken *et al*., 1991). dbh was measured using a diameter tape.

Moisture content

Oven dry method was used to measure moisture content (Omoniyi and Olorunnisola, 2014). Initial weight of (2cm * 2cm * 2cm) samples were taken and then samples were dried in an oven at 105^0C for 24 hours until a constant weight was obtained. Then the samples were transferred in to a desiccator and kept until attained room temperature. After that, oven dried weights were recorded. They were measured using an electronic balance to an accuracy of three decimals.

$$\boldsymbol{Percentage\ of\ Moisture\ content\ (wet\ basis)} = \left(\frac{\boldsymbol{W1-W2}}{\boldsymbol{W1}}\right) * \boldsymbol{100}\ Eq.\ (\ 1\ )$$

was used to calculate moisture content in wet basis

$$\boldsymbol{Percentage\ of\ Moisture\ content\ (wet\ basis)} = \left(\frac{\boldsymbol{W1-W2}}{\boldsymbol{W1}}\right) * \boldsymbol{100}\ Eq.\ (\ 1\ )$$

Where

      W1 = Initial weight
      W2 = Oven dry weight

Wood density

Four samples with dimension similar to match sticks were prepared from each extracted disk. The samples were dried in an oven at 105 ^{0}C for 24 hours. Then the samples were transferred in to a desiccator and kept them until cooled down to room temperature. After that, oven dry weights were measured using an electronic balance to an accuracy of three decimals.

Volumes of samples were determined using water displacement method. Oven dried sample were dipped in a distilled water beaker for 24 hrs. When the samples become saturated, each sample was taken from water and excess water was removed by tamping with a tissue paper. Then density of each sample was calculated using equation 02

$$\boldsymbol{Wood\ density} = \frac{Wt}{Vl}$$
$$\boldsymbol{Eq.\ (\ 2\ )}$$

Where;

  Wt = Oven dry weight of sample
  Vl = Volume of sample

Specific gravity

Specific gravity was estimated according to maximum moisture content method (Smith, 1954). For each individual, four replicates, with dimension similar to match sticks were prepared. To absorb maximum moisture, samples were immersed in distilled water for 24 hrs. When the samples become saturated, each sample was taken from water and excess water was removed by tamping with a tissue paper. After that using an electronic balance, green weight was measured to an accuracy of three decimals.

After weighing green weight, samples were oven dried at 105 ^{0}C for 24 hours until a constant weight was obtained. Then the samples were transferred in to a desiccator until room temperature was obtained. After that oven dry weights were recorded. To calculate specific gravity, equation 03 was used (Smith, 1954).

$$\boldsymbol{SG} = \frac{1}{\left(\frac{Mm-Mo}{Mo}\right)+\frac{1}{1.53}} \qquad \boldsymbol{Eq.\ (\ 3\ )}$$

Where;

  SG = Specific gravity of food
  Mm = Green weight of the sample

Mo = Oven dry weight of the specimen

1.53 is the specific gravity of the wood cell wall substances

Ash content

Loss of ignition method was used to determine ash content of each sample (Kumar et al., 2011). Four replicates samples from each selected individual were dried in an oven at 105^0C for 24 hours until a constant weight was obtained. Then the samples were transferred in to a desiccator and kept them until room temperature was obtained. After that oven dry weights were recorded. They were measured using an electronic balance to an accuracy of three decimals. After that oven dry samples were ignited in a muffle furnace at 575^0C for 4 hours. To estimate ash content of each sample on an oven dry weight basis, equation 04 was used (Kumar et al., 2011).

Ash (%) $= \left(\frac{W2-W1}{W3}\right) * 100$ *Eq. (4)*

Where;

   W1 = Weight of crucible
   W2 = Weight of crucible + ash
   W3 = Oven dry weight

Volatile matter

To determine the percentage of volatile matter of the samples, samples from previous determination of moisture content were used. Crucibles with the samples were covered. Then they were heated in the muffle furnace at 950 ± 20^oC for 7 minutes. Then the samples were transferred in to a desiccator and kept them until room temperature was obtained. After that final weights of crucible and residues were recorded. They were measured using an electronic balance to an accuracy of three decimals. Using equation 05, percentage of volatile matter of the sample was determined (Khardiwar et al., 2013).

Volatile matter (%) $= \left(\frac{W2-W3}{W1}\right) * 100$ *Eq. (5)*

Where;

   W1 = Initial weight of sample
   W2 = Weight of oven dry sample
   W3 = weight of residues + crucible

Fixed carbon content

Fixed carbon content was calculated by taking the sum of ash content percentage and volatile matter percentage then subtracted from 100 as in the equation 06 (Omoniyi and Olorunnisola, 2014).

$$\boldsymbol{Fixed\ carbon}\ (\%) = \boldsymbol{100} - (\boldsymbol{Vm} + \boldsymbol{Ac}) \qquad\qquad Eq.\ (\ 6\ )$$

Where;

        Vm = Percentage of volatile matter
        Ac = Percentage of Ash content

Biomass - ash ratio

Biomass - ash ratio was calculated by dividing oven dry weight of the samples by ash weight (Chettri and Sharma, 2009).

Calorific value

ASTMD 5865 standard procedures (Sutcu et al., 2013) were used to determine gross calorific values of each sample. According to fuel wood standards, to obtain calorific value of fuel wood, oven dried samples are used. Therefore, samples were kept in an oven at 105^0C for 24 hours. Using digital bomb calorimeter calorific values were obtained.

The procedure was carried out with the help of INSEE Cement (Lanka) Ltd, Puttalam

Fuel wood Value Index (FVI)

By using calorific value, wood density, ash content, and moisture content, FVI were calculated using equation 07. In the FVI index ash content and moisture content were given in ratios (g/g), density was given in (g/cm^3), and calorific value in kJ/g (Rai et al., 2002).

$$\boldsymbol{FVI} = \frac{\boldsymbol{Cv*Dw}}{\boldsymbol{Ac*Mc}} \qquad\qquad Eq.\ (\ 7\ )$$

Where;

        Cv = Calorific value (kJ/g)
        Dw = Wood density (g/cm^3)
        Ac = Ash content (g/g)

Mc = Moisture content (g/g)

Statistical analysis

The values for moisture content, density, specific gravity, ash content, volatile matter, and fixed carbon content of each dbh classes were subjected to one-way ANOVA in MINITAB version 14 after following Anderson Darling Normality test. Moisture content, ash content and volatile matter content and fixed carbon content (percentage values) were subjected to arcsine transformation before doing normality test. Tukey's pair wise comparison was carried out in pair wise manner to test for significant difference between three dbh classes for each measured parameters.

Results

Industrial survey

According to the industrial survey, 100% of respondent industries (n=14) utilize biomass boilers and apart from that 40% of them have furnace oil boilers, 20% factories have boilers which are operated from saw dust and 13.33% of respondent factories use diesel boilers.

All respondent industries in their biomass boilers mainly used rubber wood. Other than that mix fuel woods such as Albezia (*Albizia lebbeck*), Mango (*Mangifera indica*),Ginikuru (*Alstonia macrophylla*), Gliricedia *(Gliricidia sepium)* and some other minor species extracted from the nearby unmanaged forest were used as fuel wood. Reasons for consuming fuel woods for their boilers are low cost, high energy capacity and also to maintain the high quality of their output. According to the survey respondent industries experience some disadvantages due to utilizing fuel woods. They can be identified as high amount of ash production and low availability of woods in some periods of the year.

100% of respondent industries daily buy fuel wood for their factories from fuel wood suppliers and saw mills. 80% of respondent factories use fire woods and log woods branches and stem as fuel woods. 20% of respondents use tree roots and 13.33% factories use bark as fuel woods in their boilers. Size and moisture content are the only factors that they concern when they are buying fuel woods.

All the respondents use mixture of fuel wood species in different tree components. Because of that fuel becomes a heterogeneity mixture which leads to low efficiency.

Household questionnaire survey

A household questioner survey was conducted to identify a potential fuel wood species widely grown in the area.30 households were surveyed. The study population consists of households use fuel wood for boiling water, cooking, boiling paddy and subsistence energy needs of small scale ventures etc**.**

For their day to day activities they use Nataw (*Xylopia parviflora*), Kanda (*Macaranga peltata*), Ginikuru (*Alstonia macrophylla*), Cinnamon (*Cinnamomum zeylanicum*), Milla (*Vitex pinnata*), Rabutan (*Nephelium lappaceum*), Ahala (*Cassia fistula*), Madatiya (*Adenanthera pavonina*), Mango (*Mangifera indica*) and Tea (*Camellia sinensis*) as a fuel wood sources.

Based on the survey results 80% of households use Nataw (*Xylopia parviflora)* followed by Cinnamon as these two species provide high heat. Therefore, Nataw was identified as a potential fuelwood species which can be found in the study area.

Evaluation of fuel wood characteristics of Nataw (Xylopia parviflora) in pre-selected diameter classes

In the study site DBH of *X parviflora* vary between 5 - 35cm. Three diameter classes were identified (X) 5 - 15 cm, (Y) 15 - 25 cm and (Z) 25 - 35 cm. Five individuals from each DBH class was selected.

Mean moisture content, mean wood density, mean specific gravity, mean ash content, mean biomass ash ratio, mean calorific value and mean fuel value index of three different DBH classes are given in Figure 1,Figure 2,Figure 3,Figure 4,Figure 5,Figure 6 and Figure 7 respectively. Initially arc-sine transformations were performed for moisture content, ash content to convert percentages values to numerous. When comparing all above parameters of these three different dbh class using One Way Analysis of Variance (ANOVA), obtained p value was higher than selected alpha value 0.05, concluding that there is no any significant difference in mean moisture contents, mean wood density, mean specific gravity, mean ash content, mean biomass ash ratio, mean calorific value and mean fuel value index among three different dbh classes.
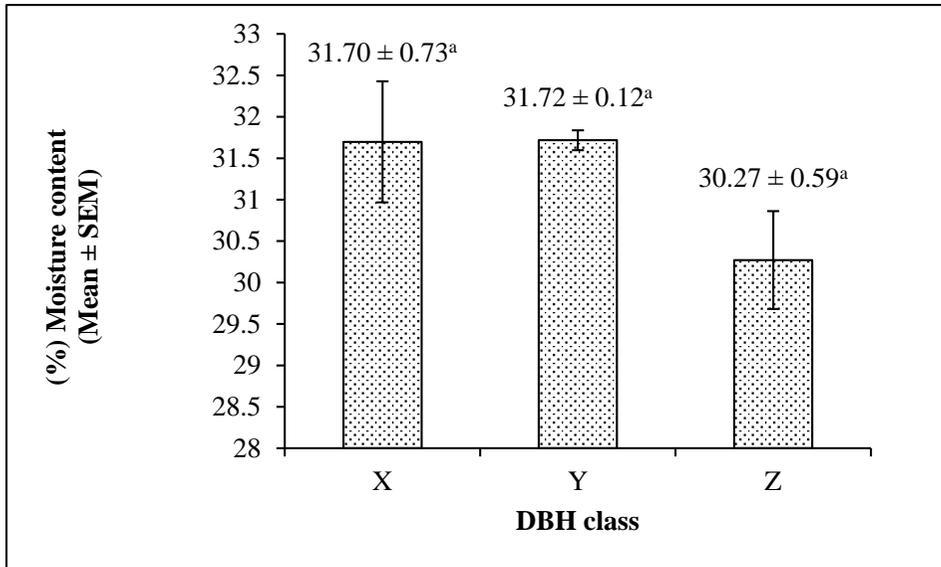
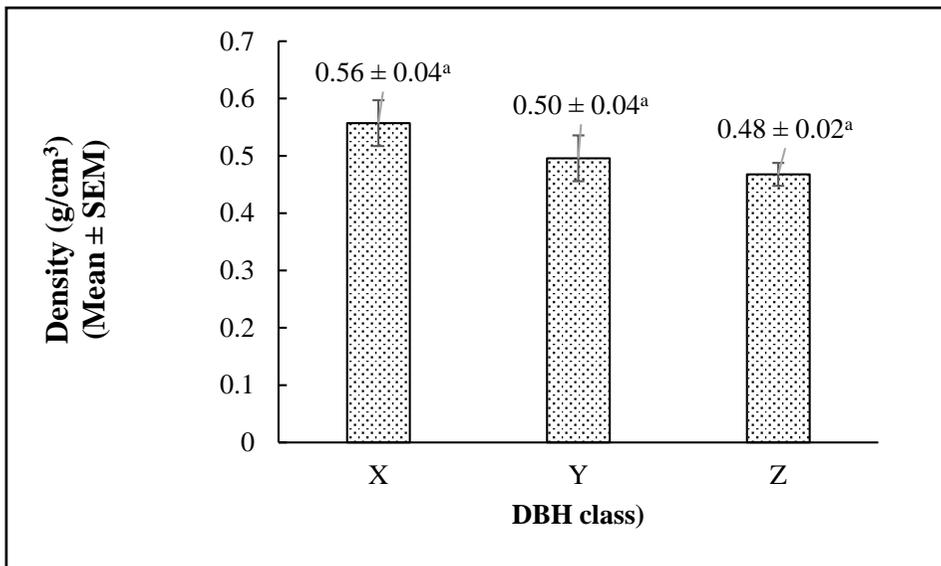**Figure 1: Mean moisture contents of three different dbh classes.**

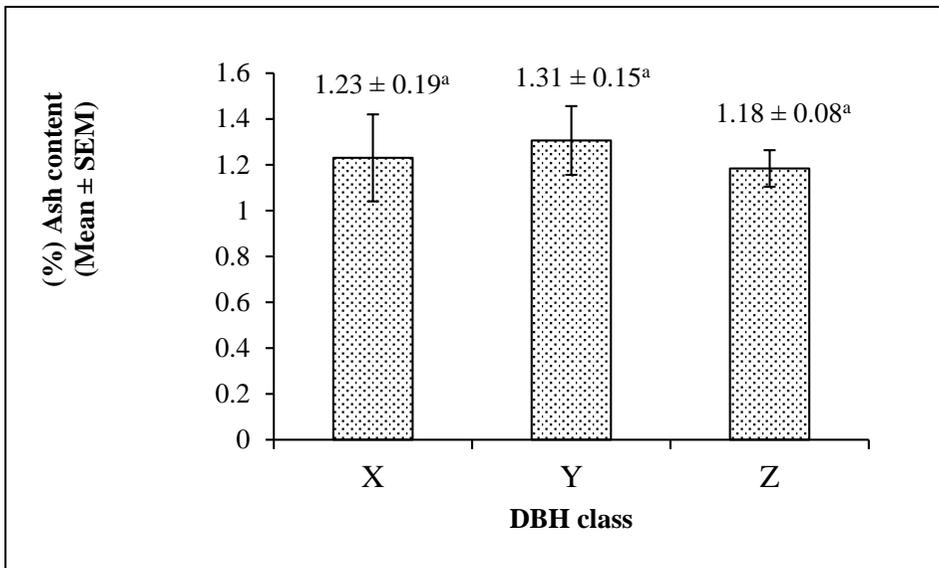**Figure 2: Mean wood densities of three different DBH classes.**

Figure 3: Mean Ash content of three different dbh classes.
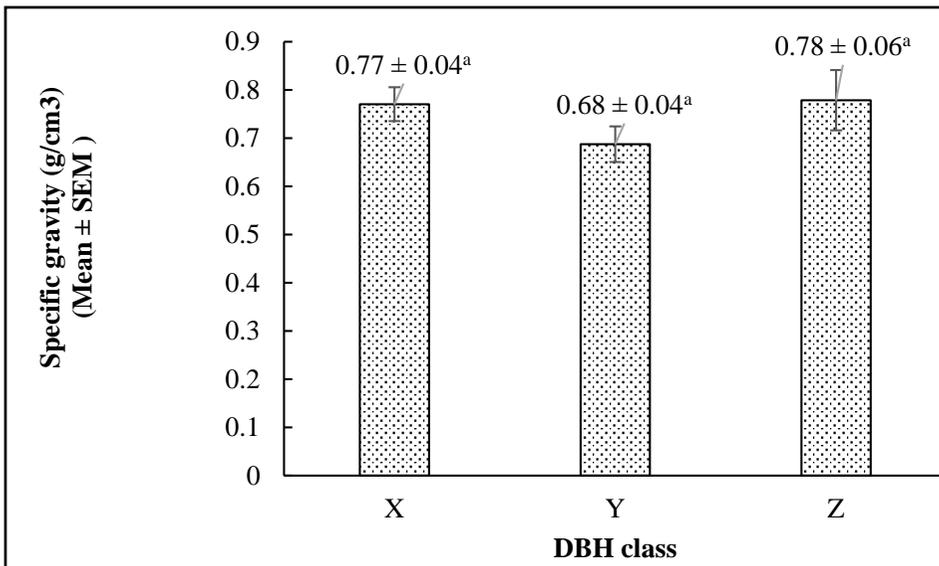

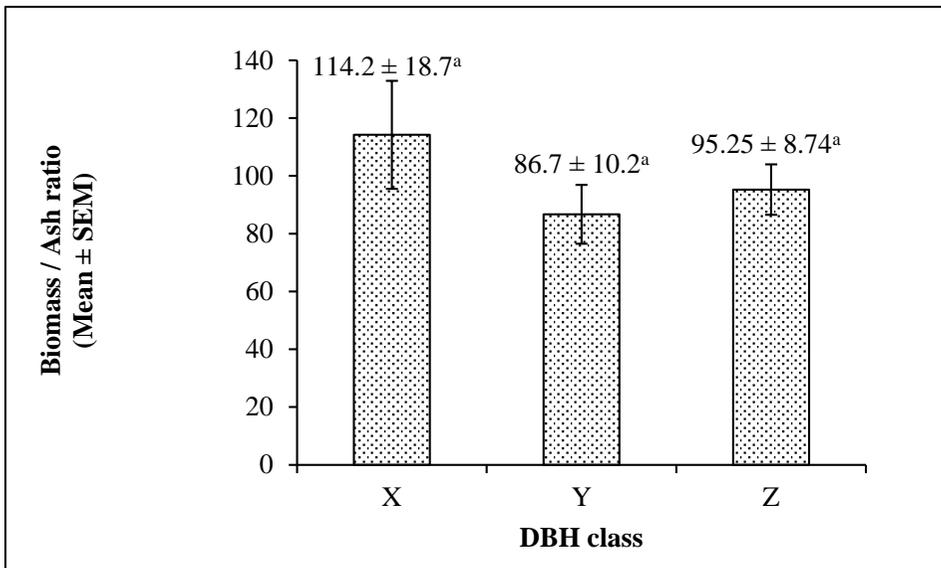**Figure 4: Mean Specific gravity of three different dbh classes.**

Figure 5: Mean Biomass/Ash ratio of three different dbh classes.
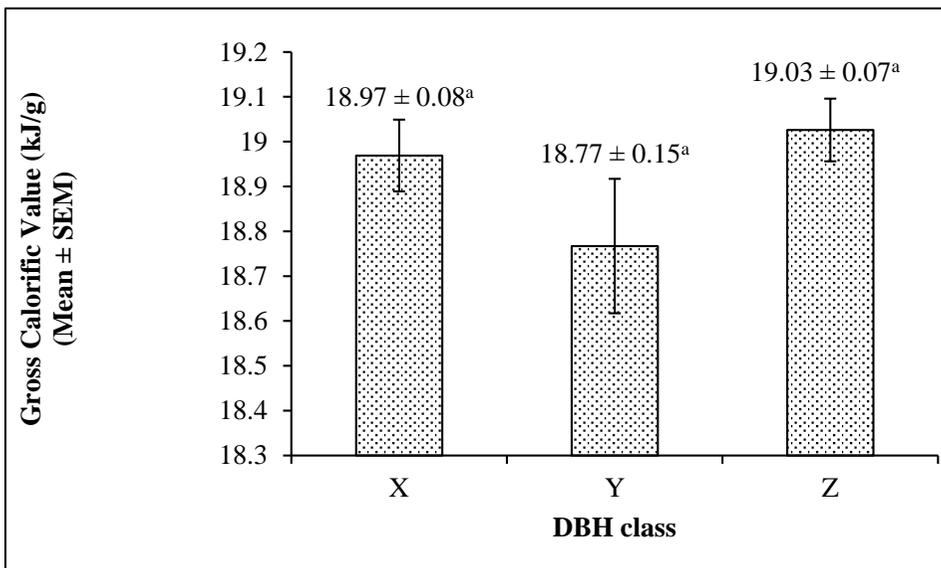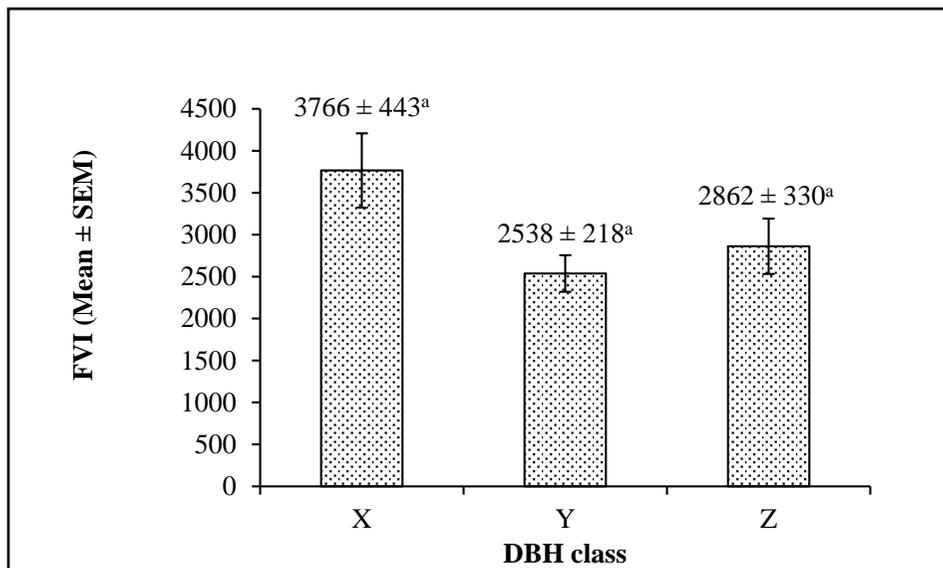

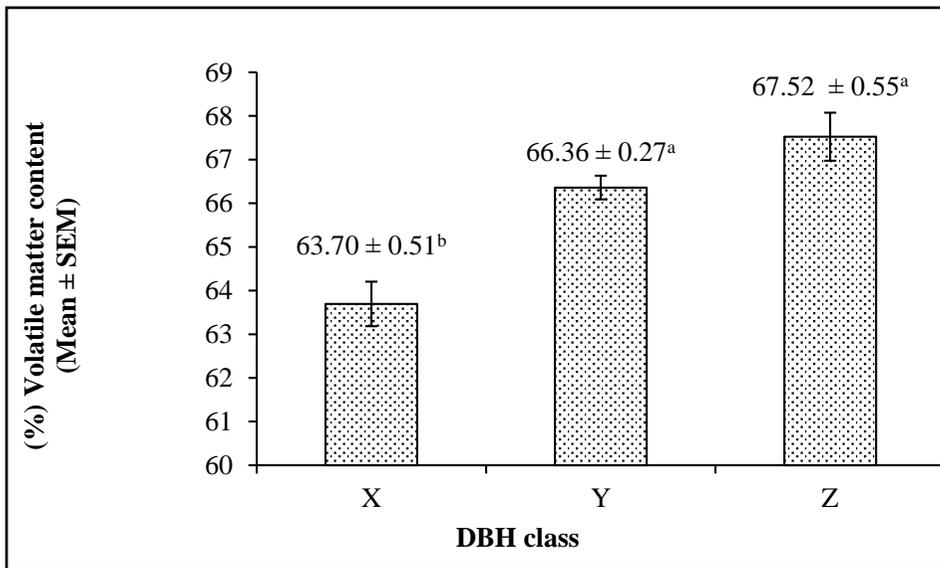**Figure 6: Mean Gross Calorific Value of three different dbh classes**

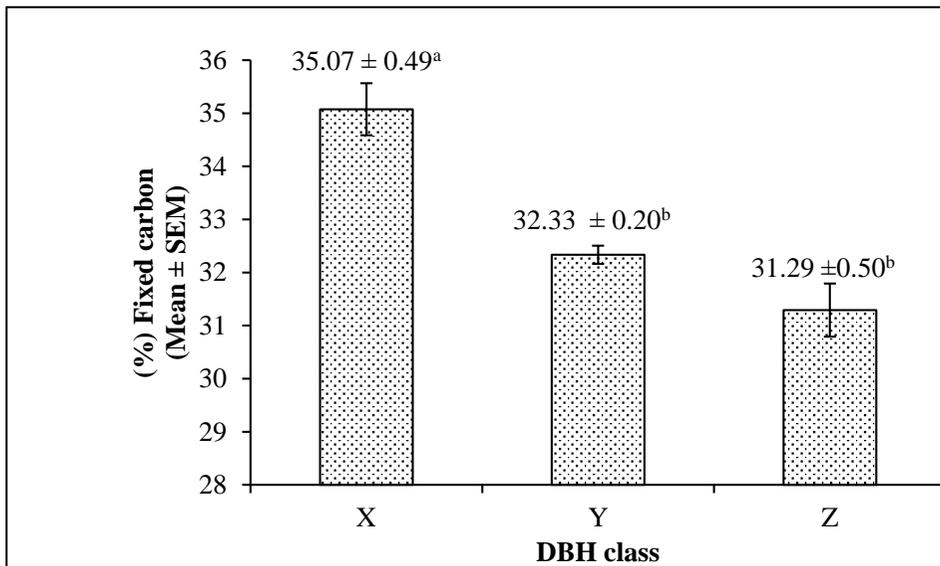**Figure 7: Mean FVI of three different DBH classes.**

Mean Volatile matter contents and mean fixed carbon content of three different DBH classes are given in Figure 8 and Figure 9. Initially arc sine transformation was performed. When comparing Volatile matter contents and fixed carbon content of these three different DBH class using One Way Analysis of Variance (ANOVA) followed by Turkey pair wise comparison, obtained p value was lower than selected alpha value 0.05, concluding that there is a significant difference in mean volatile matter contents and fixed carbon content among the three different DBH classes.

When considering volatile matter content, DBH class Z has significantly highest (67.52%) volatile matter content and DBH class X has the lowest value (63.70%). Volatile matter contents of Y and Z DBH classes are not significantly different from each other.

When considering fixed carbon content, DBH class X has significantly highest fixed carbon content (35.07%) and DBH classes Y and Z DBH classes are not significantly different from each other.

Figure 8: Mean volatile matter content of three different DBH classes and different superscript letters are significantly different from each other.

Figure 9: Mean fixed carbon content of three different DBH classes and different superscript letters are significantly different from each other

Comparisons of calorific value of *Xylopia parviflora* with calorific values of commonly used other fuel wood species in Sri Lanka.

According to UNDP (2013) records, there are nine commonly used fuel wood species in Sri Lanka. They are *Pariserianthus falcataria*, *Acacia decurrens, Clusia rosea, Leucaena leucocephala, Calliandra calothyrsus, Eucalyptus grandis, Acacia auriculiformis, Gliricidia sepium, Casurina equisitifolia.* When consider the calorific value as a measure of evaluating fuel wood species their fuel wood species calorific values range from 13.025kJ/g to 20.724 kJ/g. Calorific value of *Xylopia parviflora* (18.921 kJ/g) and mostly used fuel wood species in Kalutara district *Hevea brasiliensis* (18.740 kJ/g) lie in this range. Calorific value of *Xylopia parviflora* are more close to the most common fuel wood species in Sri Lanka, *Gliricidia sepium* (20.515 kJ/g). (Figure 10)
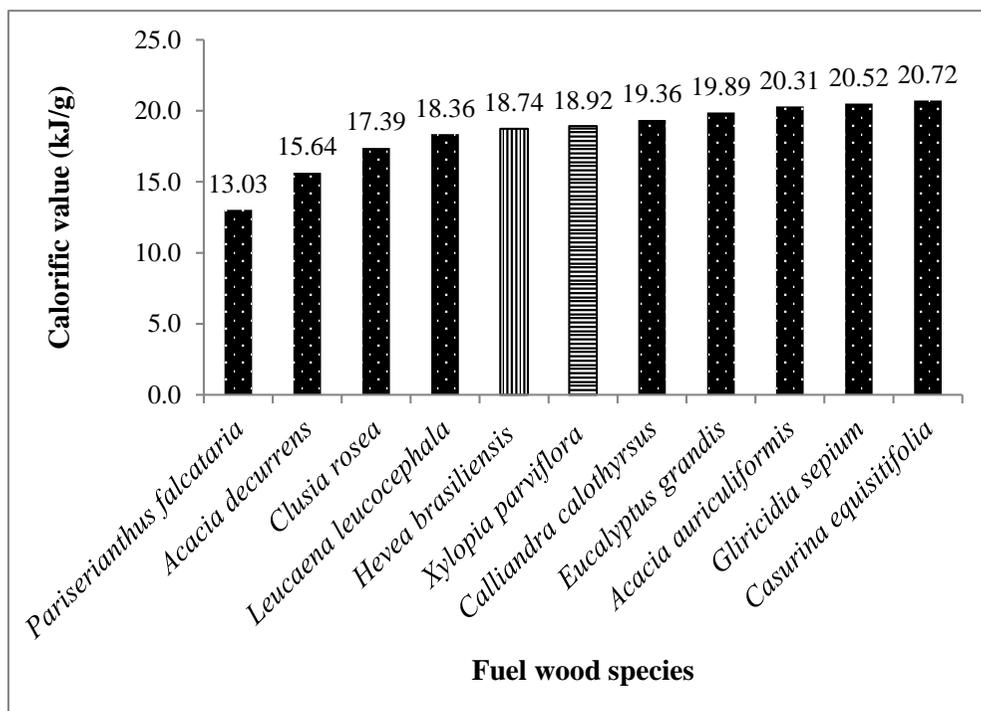
Figure 10: Graph of calorific value of commonly used fuel wood species found in Sri Lanka including *Hevea brasiliensis* and finding of the study *Xylopia parviflora*.

Fuel wood characteristics of Xylopia parviflora and Hevea brasiliensis

Fuel wood characteristics of *Xylopia parviflora* and *Hevea brasiliensis are given in* Table 2.

Table 2: Fuel wood characteristics of *Xylopia parviflora* and *Hevea brasiliensis*

Parameter	*Xylopia parviflora*	*Hevea brasiliensis*
Moisture content (%)	31.22	52
Wood density (g/cm^3)	0.507	0.778
Specific gravity (g/cm^3)	0.75	0.53
Ash (%)	1.24	2.5
Volatile matter (%)	65.86	86.3
Calorific value (kJ/g)	18.92	18.74
FVI	3055	1122

Discussion

In this study considering the diameter at breast height (dbh), Nataw (*Xylopia parviflora)* individual were divided into three classes as dbh class X (5 cm to 15 cm), dbh class Y (15 cm to 25 cm) and dbh class Z (25 cm to 35 cm) to test energy characteristics including moisture content, density, specific gravity, and ash content. In the present study dbh classes distribution have been considered to describe the plant populations. Because age class distribution in plant is not suitable to describe plant populations since the age distribution is less significant than size distribution (Perera and Gunarathne, 2014).

In the present study, when considering the moisture content, density, specific gravity, and ash content of dbh classes, there is no significant difference between among them. According to the study, which has been carried out by Dias and Marenco, (2016) has shown that, there is no significant difference between the DBH classes and the moisture content Complying with this finding, in present study, there is no significant difference between the dbh classes and the moisture content. When considering density Chudnoff and Geary (1973) have found no significant relationship between tree size and wood density. That might be the possible reason for the present finding. Complying with the results of specific gravity of present study, Navarro (2013) has

proved that the diameter of tropical species does not significantly affect or not a determining factor of specific gravity.

When considering the volatile matter content and the fixed carbon content of dbh class Y (15 cm to 25 cm) and dbh class Z (25 cm to 35 cm) has significantly higher volatile matter content and significantly lower fixed carbon content than the dbh class X (5 cm to 15 cm). Although, according to statistical analysis there is no significance difference in volatile matter content and fixed carbon between the DBH class Y and Z, dbh class Z has highest volatile matter content (67.52%) and the lowest fixed carbon content (31.29%) than dbh class Y. This may be due to the fact that when tree grows, volatile matter content of the stem would be increases.

According to the present finding there is no any significance difference of gross calorific value and fuel value index among dbh classes. Although there is no any significance difference according to the statistical analysis, dbh class Z (25 cm to 35 cm) has highest gross calorific value (19.03 kJ/g). According to the results of current study *Xylopia parviflora* individuals of dbh class Z (25 cm to 35) can be identified as the ideal size of *Xylopia parviflora* as a fuel wood to obtain optimal efficiency.

According to the Fuelwood Resource Survey of Sri Lanka (2016) in Kalutara District has founded that high proportion (75.5%) of Rubber wood are used as fire wood than the other fire woods. To compare the overall fuel wood performances of Nataw (*Xylopia parviflora)* with fuel wood performances of Rubber (*Hevea brasiliensis), energy* characteristics such as moisture content, specific gravity, wood density, volatile matter, ash content, calorific value, fuel value index have to be consider separately.

When consider the average moisture content of *Xylopia parviflora* is 31.22%. Moisture content of *Hevea brasiliensis* is (52%) and it is higher than the *Xylopia parviflora* (Teoh and Ujang, 2011). If the moisture content is low those species are favored as fuel wood because they show good combustion characteristics and higher net calorific values (Kumar et al., 2011). Therefore, *Xylopia parviflora* is more desirable than *Hevea brasiliensis* in term of moisture content.

Wood density is another important fuel wood characteristic. According to the information which was obtained from Rubber Research Institute, Agalawaththa, Sri Lanka wood density of *Hevea brasiliensis* is 0.778 g/cm^3. This value is higher than the wood density of *Xylopia parviflora* (0.507 g/cm^3). When density is higher fuel wood contains more heat per unit volume (Mitchual et al., 2014).

When consider the specific gravity *Xylopia parviflora* has the higher specific gravity (0.75 g/cm^3) than the *Hevea brasiliensis* (0.53 g/cm^3) (Teoh and Ujang, 2011). Shanavas and Kumar (2003) have proved in their study that the specific gravity varies

from species to species depending on the chemical nature or anatomical structure. That may be the reasons for difference of specific gravity of two species.

According present study, ash content of *Xylopia parviflora* is 1.24%. A study that has been carried out by Jahan *et al*., (2011) has obtained ash content of *Hevea brasiliensis* as 2.5%. According to this *Xylopia parviflora* has lower ash content than the *Hevea brasiliensis.* Ash content is also considered as important fuel wood characteristic that affect the energy performance of fuel wood. It is considered as negative attribute. Because ash means considerable part of the volume cannot be converted in to energy. An also it may affect the handling and the processing of boilers (Mitchual *et al*., 2014). Due to the low ash content of *Xylopia parviflora* it can be considered as good fuel wood species.

When consider the volatile matter content of *Xylopia parviflora* (65.86%) is lower than that of *Hevea brasiliensis* (86.3%) (Shariff et al., 2016). High volatile matter gives a measure of how the biomass to be utilized in combustion. It refers part of a biomass material that is released as volatile gases when it is heated up to 400˚C to 500˚C (Mitchual *et al*., 2014).

Calorific value is also important fuel wood characteristic which is an expression of the energy content release or heat release when it burns air. According to the present study, calorific value of *Xylopia parviflora* is 18.92 kJ/g. According to the study that has been carried out by Leong (1983), calorific value of *Hevea brasiliensis* is 18.74kJ/g. Calorific value of both species are very close to each other.

As mentioned above Fuel Value Index (FVI) is very important parameter to determine desirable fuel wood species. If the fuel wood species has high FVI, that species perfume well as the fuel wood. According to the present study FVI of *Xylopia parviflora* is 3055 and FVI of *Hevea brasiliensis* is 1122. Some studies have showed that high calorific value, low ash content, low wood moisture are highly desirable fuel wood properties and fuel wood species with those properties have FVI over 2000 (Chettri and Sharma, 2007). Result of present study proves the applicability of *Xylopia parviflora* as a good fuel wood species.

According to the present study, *Xylopia parviflora* perform well as a fuel wood than the *Hevea brasiliensis* which is commonly use fuel wood in industrial boilers in Kalutara district.

When consider the rubber plantation in Sri Lanka in 2012, replanting rate of rubber is 3% and in 2016 it is reduced to 1.5**%.** According to the Rubber Research Institute statistics (2012) , extent of estates and large size smallholders (>= 20 ha)of rubber plantation has declined by 5200 ha in main districts (Kalutara, Kegalle, Ratnapura & Galle) due to crop diversification (plantation sector statistical pocket book 2012)..

According to these information, it is clear that amount of rubber wood available as fuel wood has been gradually decreasing and industries which are using biomass boilers have to face issues due to lack of biomass supply. Therefore, it is necessary to have fuel wood plantation, in Kalutara district. If *Xylopia parviflora* can be cultivated as fuel wood in Kalutara district it can be helpful in fulfilling the energy requirement of industries which highly depend on the fuel wood due to good performance of *Xylopia parviflora* than *Hevea brasiliensis* as a fuel wood. According to the Forest Department, Sri Lanka, statistics there is a large area OF 400ha of pinus plantation in Handapangoda , Kalutara area which is planning to replace with Hora (*Dipterocarpus zeylanicus*)after uprooting pinnus. By today, about 100ha of the area has been replanted with Hora (*Dipterocarpus zeylanicus*) tree. If this replacement can be done with certain proportion of *Xylopia parviflora* plant as a buffer this will help to achieve energy requirement in Kalutara district industries which depend unreliable rubber species as a fuel.

Xylopia parviflora is not only important as the fuel wood and some studies have shown that oil extracted from fruit of *Xylopia parviflora* lead to anticancer therapy (Bakarnga-Via et al., 2014). The antimicrobial and anti-inflammatory activities of the oil also have the potential to be utilized (Woguem et al., 2014).

Conclusion

According to the study of fuel wood characteristics of Nataw (*Xylopia parviflora*) in pre-selected diameter classes, there were no significant difference among three dbh classes for moisture content, density, specific gravity, ash content, calorific value, biomass ash ratio, fuel value index. When consider the volatile matter content, dbh class Z (25cm-35cm) is significantly higher and it has lowest value for ash content than the other two dbh classes. Therefore, it can be concluded that individual of dbh class Z is more suitable for energy production. When consider the calorific value and FVI as a measure of evaluating fuel wood performance, all the three diameter classes of Nataw can be used as a heterogeneous mixture for biomass boilers.

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