Evaluation of fuel wood quality of four tree species used for fish smoking in the Sene District of the Brong Ahafo Region of Ghana

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ABSTRACT

The fuel wood quality of four trees, *Terminalia avicennoides*, *Anogeissus leiocarpus*, *Combretum ghasalense* and *Pterocarpus erinaceus*, which are easily available and widely used as fuel wood for fish smoking in the Sene District of the Brong Ahafo Region of Ghana, was assessed. The specific gravity, calorific values, and burning times were determined. The mean specific gravity values for *T. avicennoides*, *A. leiocarpus*, *C. ghasalense*, and *P. erinaceus* were 0.97, 0.96, 0.96, and 0.97, respectively. These values were not significantly different (P<0.05). The calorific values were 19,368.0 kJ/kg for *T. avicennoides*, 18,905.2 kJ/kg for *A. leiocarpus*, 18,665.8 kJ/kg for *C. ghasalense*, and 19,694.1 kJ/kg for *P. erinaceus*. The values were not significantly different (P<0.05) between *T. avicennoides* and *A. leiocarpus*, *T. avicennoides* and *P. erinaceus*, and *A. leiocarpus* and *C. ghasalense*. However, there were significant differences (P<0.05) in the calorific values between *T. avicennoides* and *C. ghasalense*, *A. leiocarpus* and *P. erinaceus*, and *C. ghasalense* and *P. erinaceus*. The time in minutes required in burning equal lengths (60 cm) of the four species of fuel wood were 360 for *T. avicennoides*, 260 for *A. leiocarpus*, 195 for *C. ghasalense*, and 175 for *P. erinaceus*. These values were significantly different (P<0.01), with *P. erinaceus* burning almost twice as fast as *T. avicennoides*. Ranking the four fuel wood species from least to highest burning times, *T. avicennoides* burnt slowest, followed by *A. leiocarpus*, *C. ghasalense*, and *P. erinaceus*. The specific gravity and calorific values recorded indicate that wood from the four species is suitable for use as fuel. *Terminalia avicennoides*, which burnt slowest, was most preferred for fish smoking, followed by *A. leiocarpus* and *C. ghasalense*. The fast-burning *P. erinaceus* was least preferred for fish smoking.

RÉSUMÉ

NERQUAYE-TETTEH, G. A., QUASHIE-SAM, S. J. & DASSAH, A. L.: *Evaluation de la qualité de bois de feu de quatre espèces d'arbre utilisés pour le fumage de poisson dans le district de Sene de la région de Brong-Ahafo du Ghana.* La qualité de bois de feu de quatre arbres, *Terminalia avicennoides*, *Anogeissus leiocarpus*, *Combretum ghasalense* et *Pterocarpus erinaceus* qui sont facilement disponibles et communément utilisés comme un bois de feu pour le fumage de poisson dans le district de Sene de la région de Brong Ahafo du Ghana, était évaluée. Le poids spécifique, la valeur énergétique et le temps de brûlé étaient déterminés. Les valeurs moyennes de la densité pour *T. avicennoides*, *A. leiocarpus*, *C. ghasalense* et *P. erinaceus* étaient respectivement 0.97, 0.96, et 0.97. Ces valeurs n'étaient pas considérablement différentes (P< 0.05). Les valeurs énergétiques étaient 19,368.0 kj/kg pour *T. avicennoides*, 18,905.2 kj/kg pour *A. leiocarpus*, 18,665.8 kj/kg pour *C. ghasalense* et 19,694.1 kj/kg pour *P. erinaceus*. Les valeurs n'étaient pas considérablement différentes (P < 0.05) entre *T. avicennoides* et *A. leiocarpus*; *T. avicennoides* et *P. erinaceus*; et *A. leiocarpus* et *C. ghasalense*. Il y avait, cependant, des différences considérables (P<0.05) dans les valeurs énergétiques entre *T. avicennoides* et *C. ghasalense*; *A. leiocarpus* et *P. erinaceus*; et *C. ghasalense* et *P. erinaceus*. Le temps en minutes exigé pour brûler les mêmes longueurs (60 cm) de quatre espèces de bois de feu étaient 360, pour *T. avicennoides*, 260 pour *A. leiocarpus*, 195 pour *C. ghasalense* et 175 pour *P. erinaceus*. Ces valeurs étaient considérablement différentes (P< 0.01), avec *P. erinaceus* brûlant presque deux fois plus vite que *T. avicennoides*. Classant les quatre espèces de bois de feu du moindre au plus haut temps de brûlé, *T. avicennoides* brûlait le plus lentement, suivi par *A. leiocarpus*, *C. ghasalense* et *P. erinaceus*. En se basant sur les valeurs de la densité et des valeurs énergétiques obtenues, le bois de quatre espèces est convenable pour être utiliser comme un com-

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bustible. *T. avicennoides*, qui brûlait le plus lentement était le plus préféré pour le fumage de poisson, suivi par *A. leiocarpus* et *C. ghasalense*. *Pterocarpus erinaceus* qui brûle vite, était le moins préféré pour le fumage de poisson.

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Introduction

The use of wood as source of energy for fish smoking is widely practised in Ghana. Fuel wood is defined as wood and pulp material obtained from the trunks, branches, and other parts of trees and used as fuel. The particular species of wood used for fuel depends on what is available in a given locality.

Although all kinds of plants are used as fuel, trees are preferred (Puri, Singh & Bhusan, 1994). Corder (1973) reported that 43 per cent of wood cut worldwide was for fuel. He recorded variations in the use of wood for fuel. The more industrialized countries use less fuel wood compared to the less industrialized countries. It is estimated that fuel wood and charcoal are the main source of fuel (85-95 %) for the Sene and Atebubu Districts of the Brong Ahafo Region of Ghana (Asare & Osei Bonsu, 1993).

The choice of wood as fuel for fish smoking depends on factors related to its physical characteristics and how they affect the product (Nerquaye-Tetteh, 1985; Lartey, Asiedu & Okeke, 1994). Hardwoods are preferred because they produce hotter fires, less smoke, and burn for longer periods than softwoods (Asare & Osei Bonsu, 1993).

Specific gravity and calorific values are the most important physical properties which affect wood use in its pulp yield, paper-making properties, wood-strength properties, hardness, and heat value (Corder, 1973; Kubler, 1980; Middleton, 1989). Specific gravity is a measure of the amount of cell wall per unit volume of wood, whilst calorific value is a measure of fuel value per unit mass of wood (Middleton, 1989). The heat transmission of wood increases with specific gravity. A denser wood is reported to release more energy (Chow & Lucas, 1988; Haygreen & Bowyer, 1983). Wood density is also widely known to positively correlate with the calorific value (Deol, 1983; Singh, Khanduja & Srivastava, 1984; Chow & Lucas, 1988; Jain, 1990; Tietema *et al.*, 1991). The burning properties of wood used as fuel are also important in selecting wood for fish smoking in Ghana (Lartey *et al.*, 1994).

Fish smoking has been practised over centuries in various parts of Ghana, and the fuel woods used have been documented (Kordylas *et al.*, 1982; Nerquaye-Tetteh, 1985; Asare & Osei Bonsu, 1993; Lartey *et al.*, 1994). However, reports on the wood quality of various species of trees as fuel energy source are limited.

The purpose of this study was to evaluate the fuel wood quality of four tree species used for fish smoking in the Sene District of the Brong Ahafo Region of Ghana, where fish smoking is an important economic activity. The specific objectives were to identify tree species used as fuel wood for fish smoking in the Sene District and to determine the energy characteristics of the identified trees.

Materials and methods

The study used primary and secondary data sources. Five communities were selected, based on their main economic activities such as fish smoking and/or fuel wood trading, easy accessibility, and ready cooperation with the study team. The Sene District is the largest of 13 administrative districts in the Brong Ahafo Region.

A survey was conducted in three of the five communities, using a structured questionnaire, to collect information on fish smoking and fuel woods used. The questionnaire was administered to 20 fish smokers purposefully and randomly selected in each of the three communities, namely, Deifour Battor, Kojokrom, and Kajaji. The results of the survey were used to select four tree species easily available, and their quality was assessed. The species of fuel wood were *T. avicennoides*, *A. leiocarpus*, *C. ghasalense*, and *P. erinaceus.*

Samples of the four fuel wood types were collected simultaneously from three locations in each of the five communities. The fuel wood samples were labelled as *T. avicennoides* (TA), *A. leiocarpus* (AL), *C. ghasalense* (CG), and *P. erinaceus* (PE). The communities were labelled as Deifour Battor (DB), Kojokrom (KJ), Kajaji (KA), Chaboba (CH), and Nketia Akuraa (NA). The three locations where the fuel woods were collected in each community were also labelled as 1, 2, and 3. All the fuel wood samples were therefore identified under their respective tree species (Table 1). The sample size was 60.

From the collection, 15 replicates of each type of the four tree species were produced and used for the study. Pieces of fuel wood measuring 25 cm in length were cut from each sample of the four batches of wood species and labelled accordingly, TA/DB1 to PE/NA3 (Table 1).

Determination of specific gravity of fuel wood samples

Five specimens of about 2 cm × 4 cm × 2 cm were prepared from each of about 4-cm sawn blocks of the fuel wood samples. They were labelled accordingly and placed in polyethylene bags to avoid excessive uptake of moisture from the atmosphere. Five replicates were produced from each fuel wood sample. A total of 75 specimens was obtained from each lot, producing

TABLE 1

Fuel Wood From Species Obtained From Three Locations 1, 2, 3 in Each of Five Communities - Deifour Battor (DB); Kojokrom (KJ); Kajaji (KA); Chaboba (CH) and Nketia Akuraa (NA) in the Sene District

Community	*Location*	*Fuel wood species*			
		T. avicennoides	A. leiocarpus	C. ghasalense	P. erinaceus
Deifour Battor	1	TA/DB1	AL/DB1	CG/DB1	PE/DB1
	2	TA/DB2	ALDB2	CG/DB2	PE/DB2
	3	TA/DB3	ALDB3	CG/DB3	PE/DB3
Kojokrom	1	TA/KJ1	AL/KJ1	CG/KJ1	PE/KJ1
	2	TA/KJ2	AL/KJ2	CG/KJ2	PE/KJ2
	3	TA/KJ3	AL/KJ3	CG/KJ3	PE/KJ3
Kajaji	1	TA/KA1	AL/KA1	CG/KA1	PE/KA1
	2	TA/KA2	AL/KA2	CG/KA2	PE/KA2
	3	TA/KA3	AL/KA3	CG/KA3	PE/KA3
Chaboba	1	TA/CH1	AL/CH1	CG/CH1	PE/CH1
	2	TA/CH2	AL/CH2	CG/CH2	PE/CH2
	3	TA/CH3	AL/CH3	CG/CH3	PE/CH3
Nketia Akuraa	1	TA/NA1	AL/NA1	CG/NA1	PE/NA1
	2	TA/NA2	AL/NA2	CG/NA2	PE/NA2
	3	TA/NA3	AL/NA3	CG/NA3	PE/NA3

a grand total of 300 specimens. The specimens were oven dried at 103 ° C ± 2 ° C for 48 h to a constant weight and then used. The hydrostatic method as illustrated by Brown, Panshin & Forsaith (1952), and also described in the Standards and Suggested Methods of the Technical Association of Pulp and Paper Industry (TAPPI, 1972), was used to determine the specific gravity.

According to Brown *et al.* (1952) and Dinwoodie (1989), specific gravity is computed from the following equation:

$$\text{Specific gravity} = \frac{\text{Oven dry mass of specimen}}{\text{Mass of displaced volume of water}}$$

Determination of calorific value of fuel wood samples

Three specimens were prepared from each of the fuel wood samples. A total of 45 specimens was obtained from each lot of sample of fuel wood (i.e.,180 specimens). The samples were oven dried to a constant weight at 103 °C ± 2 °C. The bomb calorimetric method was used in determining the calorific value.

The calorific value of each specimen was calculated by using the following formula:

$$W_f \times Q = (W_w + W_a) \text{ rise in temperature } ^\circ\text{C} \times 4.2$$

where W_f kg is the weight of fuel wood, Q kJ/kg is the calorific value, W_w g is the weight of water in the calorimeter vessel, and W_a kg is the "water equivalent of the apparatus (0.482) (Mtetwa & Vilakati, 1983).

Determination of burning properties of fuel wood

A method was designed to determine the burning times of the four species of fuel wood. Five pieces each of the four fuel woods were taken from each lot of fuel wood samples. The pieces were about 10 cm in diameter. Each piece was marked at 15-cm intervals lengthwise, from 0 to 60 cm. Five burning trials were done. For each trial, one piece each of the marked four species of fuel wood were arranged and burnt together in one Chorkor Smoker at a time. The time in minutes it took for each species of fuel wood to burn to the mark 60 cm was noted for each of the five trials designated a, b, c, d, e.

Statistical analysis

The data were statistically analysed with the Paired T-test, analysis of variance (ANOVA), and the least significance difference test (LSD).

Results and discussion

Fuel woods used for fish smoking in the Sene District

Various species of fuel wood were used for fish smoking in the Sene District. These included *Vitex doniana, Butyrospermum parkii, Anogeissus leiocarpus, Combretum ghasalense, Pterocarpus erinaceus, Vernonia biafrae, Burkea africana, Pseudocedrela kotschyi,* and *Terminalia avicennoides.* Of these, *T. avicennoides, A. leiocarpus, C. ghasalense,* and *B. parkii* were most preferred because they burned slowly and generated a lot of heat, and also imparted a nice colour to the smoked product. However, the use of *B. parkii* which is an economic tree in Ghana, was limited because of the law that restricts its harvesting for fuel wood in the Sene District. Though *V. biafrae* and *P. kotschyi* are preferred for fish smoking, they are scarce probably because of over exploitation. Fig. 1 shows the different fuel woods used to smoke the fish.

Table 2 shows results of the mean specific gravity values. The values for *T. avicennoides, A. leiocarpus, C. ghasalense,* and *P. erinaceus* were 0.97, 0.96, 0.96 and 0.97, respectively. The values were not significantly different (P<0.05) among the four species. The values were higher than those recorded for some exotic tree species. NAS (1980) and Davidson (1987) reported that the wood specific gravity of *L. leucocephala* varied from 0.60 to 0.80, and that of *S. siamea* from 0.45 to 0.72. Mainoo & Ulzen –Appiah (1996) reported specific gravity values ranging from 0.63 for *S.*

a. Firewood from *Terminalia avicennoides.*

b. Firewood from *Anogeissus leiocarpus.*

c. Firewood from *Combretum ghasalense.*

d. Firewood from *Pterocarpus erinaceus.*

Fig. 1. Species of fire wood used for fish smoking.

siamea to 0.67 for *L. leucocephala*. Results reported by Francois (1998) for *L. leucocephala* and *S. siamea* varied from 0.68 to 0.80. Most species of trees reported as good fuel are known to have reasonably higher specific gravity (Chow & Lucas, 1988; Haygreen & Bowyer, 1983). The average specific gravity values indicate that the four tree species studied are good fuel.

Table 3 shows the calorific values. The mean calorific values of the fuel wood samples were 19,368.0 kJ/kg for *T. avicennoides*, 18,905.2 kJ/kg for *A. leiocarpus*, 18,665.8 kJ/kg for *C. ghasalense*, and 19,694.1 kJ/kg for *P. erinaceus*. There were no significant differences ($P<0.05$) in the calorific values between *T. avicennoides* and *A. leiocarpus*, *T avicennoides* and *P. erinaceus*, and *A. leiocarpus* and *C. ghasalense*. Significant differences ($P<0.05$) were recorded between *T. avicennoides* and *C. ghasalense*, *A. leiocarpus* and *P. erinaceus*, and *C. ghasalense* and *P. erinaceus*. The results are close to values reported by Puri *et al.* (1994) for some indigenous tree species in India.

The mean time required for burning the four species of fuel woods to the 60-cm mark were 360, 260, 195, and 175 min for *T. avicennoides, A. leiocarpus*, *C. ghasalense*, and *P. erinaceus*, respectively (Table 4). *Pterocarpus erinaceus* burnt almost twice as fast as *T. avicennoides*. There were highly significant differences ($P<0.01$) in the values evaluated by ANOVA and LSD. When the species of trees were ranked according to their burning times, *T. avicennoides* burnt slowest, followed by *A. leiocarpus*, *C. ghasalense*, and *P. erinaceus*. This was similar to what the fish smokers observed. For this reason,

TABLE 2

Mean Specific Gravity Values of Four Species of Fuel Wood*

Fuel wood	*Specific gravity*	*Fuel wood*	*Specific gravity*	*Fuel wood*	*Specific gravity*	*Fuel wood*	*Specific gravity*
TA/DB1	0.97 ± 0.009	AL/DB1	0.97 ± 0.007	CG/DB1	0.97 ± 0.006	PE/DB1	0.98 ± 0.005
TA/DB2	0.97 ± 0.006	AL/DB2	0.97 ± 0.002	CG/DB2	0.97 ± 0.006	PE/DB2	0.98 ± 0.004
TA/DB3	0.97 ± 0.008	AL/DB3	0.97 ± 0.005	CG/DB3	0.96 ± 0.008	PE/DB3	0.97 ± 0.007
TA/KJ1	0.97 ± 0.005	AL/KJ1	0.97 ± 0.009	CG/KJ1	0.96 ± 0.015	PE/KJ1	0.97 ± 0.012
TA/KJ2	0.97 ± 0.007	AL/KJ2	0.96 ± 0.012	CG/KJ2	0.98 ± 0.002	PE/KJ2	0.98 ± 0.004
TA/KJ3	0.97 ± 0.006	AL/KJ3	0.97 ± 0.006	CG/KJ3	0.97 ± 0.006	PE/KJ3	0.96 ± 0.007
TA/KA1	0.97 ± 0.004	AL/KA1	0.97 ± 0.011	CG/KA1	0.98 ± 0.001	PE/KA1	0.97 ± 0.006
TA/KA2	0.97 ± 0.008	AL/KA2	0.96 ± 0.005	CG/KA2	0.96 ± 0.005	PE/KA2	0.97 ± 0.006
TA/KA3	0.97 ± 0.007	AL/KA3	0.96 ± 0.013	CG/KA3	0.97 ± 0.010	PE/KA3	0.97 ± 0.006
TA/CH1	0.96 ± 0.012	AL/CH1	0.98 ± 0.006	CG/CH1	0.96 ± 0.011	PE/CH1	0.97 ± 0.008
TA/CH2	0.97 ± 0.005	AL/CH2	0.97 ± 0.007	CG/CH2	0.96 ± 0.005	PE/CH2	0.96 ± 0.005
TA/CH3	0.97 ± 0.008	AL/CH3	0.97 ± 0.007	CG/CH3	0.97 ± 0.007	PE/CH3	0.98 ± 0.006
TA/NA1	0.97 ± 0.005	AL/NA1	0.97 ± 0.005	CG/NA1	0.97 ± 0.005	PE/NA1	0.97 ± 0.010
TA/NA2	0.97 ± 0.008	AL/NA2	0.96 ± 0.010	CG/NA2	0.96 ± 0.007	PE/NA2	0.97 ± 0.008
TA/NA3	0.98 ± 0.005	AL/NA3	0.97 ± 0.004	CG/NA3	0.97 ± 0.011	PE/NA3	0.97 ± 0.005

*The figures are mean specific gravity values of five determinations per sample of fuel wood.

TABLE 3

Mean Calorific (kJ/kg) Values of Four Species of Fuel Wood*

Fuel wood	*Calorific value*	*Fuel wood*	*Calorific value*	*Fuel wood*	*Calorific value*	*Fuel wood*	*Calorific value*
TA/DB1	18,790.6±907.7	AL/DB1	19,424.2±163.0	CG/DB1	18,963.5±534.5	PE/DB1	20,404.5±1129.5
TA/DB2	19,770.5±1174.2	AL/DB2	18,617.9±1184.3	CG/DB2	18,963.5±570.6	PE/DB2	18,729.6±779.5
TA/DB3	19,194.0±489.1	AL/DB3	19,424.9±293.9	CG/DB3	18,674.2±244.1	PE/DB3	19,939.9±698.5
TA/KJ1	19,078.8±961.0	AL/KJ1	19,214.2±239.9	CG/KJ1	16,945.4±785.9	PE/KJ1	19,655.2±355.3
TA/KJ2	18,329.4±747.1	AL/KJ2	18,559.7±163.4	CG/KJ2	18,156.5±1487.5	PE/KJ2	19,194.3±244.4
TA/KJ3	19,078.7±81.6	AL/KJ3	17,115.7±1152.1	CG/KJ3	19,084.6±214.3	PE/KJ3	19,481.9±81.3
TA/KA1	19,655.2±991.7	AL/KA1	18,386.9±862.4	CG/KA1	19,539.9±615.4	PE/KA1	19,712.8±615.4
TA/KA2	19,655.2±696.5	AL/KA2	19,136.4±453.9	CG/KA2	18,214.2±587.8	PE/KA2	18,661.9±479.9
TA/KA3	19,462.4±854.2	AL/KA3	17,925.6±1707.6	CG/KA3	17,349.2±651.8	PE/KA3	20,139.6±314.0
TA/CH1	20,116.3±696.5	AL/CH1	19,828.1±1421.1	CG/CH1	18,502.4±224.5	PE/CH1	20,577.5±244.5
TA/CH2	19,136.4±431.3	AL/CH2	19,984.2±1417.6	CG/CH2	19,828.1±1334.5	PE/CH2	18,380.6±403.1
TA/CH3	18,835.6±650.6	AL/CH3	19,518.2±1200.3	CG/CH3	18,496.4±484.9	PE/CH3	19,567.2±631.8
TA/NA1	19.078.8±587.8	AL/NA1	18,353.7±2023.3	CG/NA1	18,732.9±587.8	PE/NA1	19,885.7±747.1
TA/NA2	20,865.6±587.8	AL/NA2	19,160.7±1344.9	CG/NA2	18,642.7±	PE/NA2	19,674.3±1006.4
TA/NA3	19,488.5±496.7	AL/NA3	19,562.1±1317.9	CG/NA3	18,963.5±163.0	PE/NA3	20,109.0±87.2

*The figures are mean calorific values (kJ/kg) of three determinations of each sample

TABLE 4

Mean Burning Time of the Four Species of Fuel Wood

Species of fuel wood	*Mean time in minutes*
Terminalia avicennoides	360^{a} ± 1.85
Anogeissus leiocarpus	260^{b} ± 1.67
Combretum ghasalense	195^{c} ± 2.28
Pterocarpus erinaceus	175^{d} ± 3.22

Mean followed by same letter, is not significantly different ($P < 0.01$) from each other. N= 5

T. avicennoides, *A. leiocarpus*, and *C. ghasalense* were preferred for fish smoking in this order than *P. erinaceus*. A combination of different species of fuel wood is often used by the women.

Conclusion

For an ideal fuel wood, high specific gravity and high calorific values are the basic desirable characteristics (Chow & Lucas, 1988; Haygreen & Bowyer, 1983). The mean specific gravity and calorific values recorded indicate that the four species of wood studied are suitable for use as fuel wood. For the burning time, *T. avicennoides, A. leiocarpus,* and *C. ghasalense* are preferred for fish smoking while *P. erinaceus* is least preferred.

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