INTERNATIONAL TROPICAL TIMBER ORGANIZATION (ITTO)

EXECUTING AGENCY: FORESTRY RESEARCH INSTITUTE OF GHANA (FORIG)

FINAL TECHNICAL REPORT NO 1: AVAILABILITY AND CHARACTERISTICS OF DIFFERENT TYPES OF WOOD RESIDUE FOR ENERGY PRODUCTION.

TITLE OF PRE-PROJECT: DEVELOPMENT OF ENERGY ALTERNATIVES FOR THE EFFICIENT UTILIZATION OF WOOD PROCESSING RESIDUE: CO-GENERATION AND BRIQUETTE PRODUCTION.

SERIAL NUMBER: ITTO PROJECT PPD 53/02/Rev.1 (1)

PLACE OF ISSUE: KUMASI, GHANA

DATE OF ISSUE: DECEMBER 2004

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ABSTRACT

The study of wood processing residues as a source of energy was preceded by the characterization of the raw material and the determination of its availability. For the characterization, important parameters associated with generation of energy from wood residue such as moisture content, ash content and its analysis, bulk density, heating values of selected wood species as well as the size of particles of sawdust generated during processing with circular and band saws were determined.

Atomic absorption spectroscopy (AAS) technique was used to analyze the ash produced by ashing sawdust at 650°C for four hours in order to determine the alkaline and transition metals contents in the ash. Sieves of different apertures were used to separate the various sizes of particles in sawdust generated from wood with circular saw and band saw .Two cubical boxes of dimensions 10cm and 15cm were constructed for the determination of bulk densities of sawdust produced with circular saw, band saw, wood mizer and chain saw. Bomb calorimeter was used to determine the heating values for oven-dried and 12% moisture contents of some selected wood species. Moisture contents of selected wood species were determined when accurate weight of samples were dried in an oven at 105°C till constant weights were realized. The availability of wood residue was determined through administration of structured questionnaires, interviews and direct on-site studies of various activities during processing of logs at the selected sawmills and plywood mills.

The mean moisture content (%) (wet basis) of *Triplochiton scleroxylon, Antaris toxicaria, Pycnanthus angolensis , Pterygota macrocapa, Ceiba pentandron and Guibourtia ehie* for sawdust and bark ranged from 41.76 to 60.00 and 40.02 and 59.19 respectively. Atomic Absorption Spectroscopy (AAS) analysis revealed the presence of the following elements : Iron , copper , lead, cadmium , zinc , calcium , sodium , potassium and magnesium in the species studied . Higher heating values for thirteen hardwood species at oven –dried and at 12% moisture content ranged from (14.2 to 20.3)MJ/kg and (8.51 to 18.2)MJ/kg respectively. Similarly, lower heating values for 10 hardwood species at oven dried and at 12% moisture content ranged from 12.4 to17.8 and 8.2 to 16.57 respectively. The study of bulk density revealed that bulk density varies depending upon the type of saw used for sawing and the type of species processed. Most of the particles of sawdust produced from circular saw and band saw were less than 2.00mm in size. Particles of sawdust retained by the sieve with pore of 0.425mm were less than 0.5%. The studies from the saw mills revealed that during processing the mills generate 12% sawdust, 20% off-cuts and 17% slabs and edgings. Also, rotary veneer residue and defective veneer were 21% and 23% respectively. Off-cuts from rotary production was 16%.

The study has revealed that recoveries of export products are very low and that much of the residues are used for the production of flooring strips, triangular mouldings and flooring parquet. However the use of residue is not optimal. There is an increasing need for its use for process heat generation. There is also the need to use sawdust for briquette production.

CHAPTER 1

INTRODUCTION

Ghana Forest Policy objective is to manage, protect, conserve and develop her forest in order to ensure sustainable wood (as well as Non-Timber Forest Products) production and utilization to optimise the economic, social and environmental benefit, to the people and to provide sustainable support for the country's forest-based industries (Ministry of Lands and Forestry, 1994). Optimisation of forest benefits is enhanced when timber products derived from the forests are processed as efficiently as possible using the most efficient technologies. Notwithstanding there are serious wood processing residues problems.

This pre-project proposal was therefore submitted by the Government of Ghana for a study of methods to address the growing but serious problem of wood processing residues. The existing wood industries generate large volumes of wood wastes, slabs, edgings off-cuts, sawdust etc.

This is evidenced by the ITTO Project PD 74/90 entitled "Better utilization of tropical timber resources in order to improve sustainability and reduce negative ecological inputs" which was undertake by Forestry Research Institute of Ghana (FORIG) and Federal Centre of Forestry and Forest Products in Hamburg, Germany. The results showed that, overall the average recovery on sawmilling in one of the three areas of study was 45% raw lumber, 8% by products, 8% sawdust and 39% solid residue. In a similar study in another area the following data were obtained-mean recovery rate of 44.1% lumber, 4.2% by products, 6.2% sawdust and 45.5% solid residue. It was estimated that wood residue in the forest floor amounted to 48%, 50% and 63% - in the three areas which were studied (Ofori et al, 1993).

In order to maximise the timber products it is possible to use the residue to generate energy for domestic and industrial application through briquetting (with and without carbonisation) and process heat and or power generation (co-generation) (Evans and Zaradic, 1996). There is other possible range of products that could be developed from the residue. These include fuelwood, paper & pulp and mechanically processed wood. The latter includes sawnwood, waferboards, fibre and particle-boards, wood composite cement board, finger-jointing timber, packaging and other products.

In 1998 an Energy sector Management Assistance Programme (ESMAP) on sawmill residue utilization by UNDP and World Bank examined the feasibility of using sawmill residues to generate both heat and electricity for use by the wood processing industries. The study concluded that since all the large mills are connected to the national grid and get low cost electricity at 3.5 US cents/KWh, there was no financial gain in the short term for mill owners to indulge in co-generation. Since then, there have been tremendous changes in the energy sectors. There have been power curtailment and rationing due to drought situations that affected hydrogeneration. This has also brought to the front the need to charge economic tariffs for electricity. Consequently there has been a steady rise in the tariffs. It is over 15years since that study was carried out.

There have also been significant changes in the processing milieu of the industry. Major changes that are likely to have effect on the scenario for co-generation from processing residues include the following:

- A ban on round log export imposed since 1995;
- Increased processing of lesser-used species;
- Increased emphasis on value-added processing
- Stricter controls and regulation of log harvesting resulting in a drastic reduction in the annual timber harvest and
- Institution of levies on the export of green lumber. This has led to an increase in the installed capacity of drying kilns.

All these factors do affect wood processing and to some extent the generation of wood residue.

Energy generated from the residue through co-generation could be used to produce electrical power and process steam for

(i) Steaming peeler blocks for plywood manufacture
(ii) Drying of lumber and
(iii) Reduce the mills dependency on the national grid.

The co-generation is an attractive alternative to the conventional power and heat generating options due to:

- Its relatively lower capital investment
- Reduced fuel consumption
- Reduced environmental pollution
- And increased fuel diversity.

Currently, Ghana's total energy generating capacity supplies approximately 65% of the national peak demand, which is growing at an annual rate of 15% (Ministry of Mines and Energy,1996). Thus, a detailed study of co-generation and its economic viability in the Ghanaian industry has become necessary due to the following:

- Increased pressure on Government to increase electricity tariff.

- Constraints faced by Government in financing additional power generating capacities
- Growing concern to limit the environmental pollution associated with energy generation and use and
- Increased industrial growth due to government's increased encouragement of privatization and private sector participation.

With the increase in production in wood industry since 1994, the rising electricity tariff rates and an investment in co-generation having a payback period of less than 5years it has become necessary to examine the economic and the potential of co-generation in the industry in order to keep the timber companies from collapse due to energy problems.

Apart from generating energy from the wood residue through co-generation, it is also possible to use the residue to produce briquette for domestic and commercial purposes. The accumulation of sawdust poses fire hazard as well as increment in running cost owing to the need to dispose of the accumulated sawdust. However, with the rising cost of fuel in homes and factories it is worth giving sawdust conversion to briquette a serious consideration. The consumption of charcoal in Ghana is projected to grow at a rate of 6% annually. (Nketiah et al, 1988). This is the result of increasing urbanization and the shift from the use of firewood to charcoal. This high rate of consumption of charcoal (Urban area) and equally high rate of firewood consumption (rural area) result in indiscriminate felling of trees. This practice will lead to the problem of deforestation, which will consequently have a negative effect on the energy situation of the country. There is therefore the need to find substitutes and/or supplement for charcoal and firewood.

Most of the previous wood energy experiences in Africa, especially under the World Bank/UNDP/ESMAP programmes have concentrated on conversion devices-their designs and efficiencies. These have included cookstove programmes in Kenya, Zambia, Botswana and Ghana. Others have focused on charcoal production efficiencies and kiln modifications.

However, very few attempts have been made at examining the briquette option. These have been very limited in scope. In fact, initial attempts in Ghana at commercial briquetting of sawdust were not very successful. The compaction of sawdust and other forms of wood residue into briquette for fuel have been successfully carried out in most advanced countries for a number of years. The problems faced in the introduction of this technology to Ghana were marketing, technical, social and economic. It is therefore important to do a comprehensive analysis of the technical, social and economic factors that affect the production, distribution, marketing and use of briquettes.

The analysis will examine the distribution cost, social acceptance and the integrity of the product itself overtime. Size of market, the willingness and the ability of people to pay for the new fuel product, types and requirements of stoves in use in the market area, environmental consideration and availability of credit subsidy to get the enterprise started. The most effective way of achieving success is to assess the situation from several viewpoints, technicians, women associations, farmers, institutional kitchens etc. These groups are a good source of information about the social climate, the attitude of local people to innovations and economic and the relevant factors.

Before any concrete decision could be taken concerning co-generation and briquette production as well as the other commercial options the availability of the residue ought to be determined. It was for this reason that 3 mills were selected to determine the volume of wood residue generated. Currently, Ghana has 110 sawmills and 24 veneer and plywood mills (Pleydell, 1994). After quantifying the volume of wood residue it was necessary to determine the characteristics of wood, which affect the generation of energy. Thus moisture content, energy content, ash content and fuel density of wood residue were also determined.

For the co-generation studies interviews were conducted to obtain the following data:

- The main activity
- Hours of operation
- Working days
- Transformer capacity
- Electrical and thermal demand patterns
- Electrical energy consumption
- Alternative source of power apart from the national grid
- Steam flow rate of boilers
- Quality and availability of fuel etc.

Where accurate data were unavailable reasonable estimations were made based on the interviews with personnel at the site. Based on what has been outlined above the development objective for the project was stated as the need to promote the domestic and industrial utilization of wood processing residues to enhance sustainable timber production and reduce environmental pollution in Ghana. The specific objective for the project was stated as identification and documentation of domestic and commercial options with emphasis on co-generation for efficient utilization of wood residue.

CHAPTER 2

AVAILABILITY AND CHARACTERISTICS OF DIFFERENT TYPES OF WOOD RESIDUE FOR ENERGY PRODUCTION

1. INTRODUCTION

The forests of Ghana are known to be rich in terms of the diversity of species both flora and fauna. They are essential resources for the country upon which manufacturing activity can be brought to bear to increase employment generation, export earnings and sustainable development. There are over 2,100 plant species, out of which 730 are tree specie (Hall & Swaine 1981). 420 of these species are common and of wide distribution (Hawthorne 1989). Of these 126 grow to timber size of which 50 are considered merchantable (François 1987).At present only about 7% of trees in the forests of Ghana are being exploited. Currently, the emphasis is on utilization of more of the many species growing in Ghana's forest.

For maximum utilization of the species it is important to study their characteristics. Particularly when the wood residue generated in the course of sawing, moulding and plywood production etc is to be used for energy generation. It is essential to know the moisture content, energy content, Ash content and fuel density of the species from which the residue was generated.

1.1. GHANA'S TIMBER INDUSTRY

1.1.1. THE SCOPE OF THE INDUSTRY

Ghana has a large number of wood processing mills which together cover virtually the range of wood products. There are about one hundred sawmills and two hundred furniture producers. Sources of sliced and rotary veneer total seventeen, for flooring the figure is at least six and there are a similar number offering doors. Plywood sources total about 10. Mouldings, profiles and machined wood are available from over forty producers and there are sources of dowels, tool handles, window frame sections, wooden toys, transmission poles and fencing(Pleydell,1994).

1.1.2. CAPACITY

Annual gross wood production from the forest is about 1.2 million cubic metres of logs, which represents the annual allowable cut (Pleydell, 1997). The annual cut is however far higher than the quoted figure because of the activities of illegal chain sawn operators. Most of the logs for export are processed before shipment. The industry is increasingly adding value by further processing. Exports of machined timber and components are rising.

2. CHARACTERISTICS OF WOOD FOR ENERGY GENERATION

2.1. MOISTURE CONTENT (m.c)

The timber of living trees and freshly felled logs contain a large amount of water, which often contributes a greater proportion by weight than the solid material itself. The water has a profound influence on the properties of wood, affecting its weight, strength, shrinkage and liability to attack by some insects and certain fungi that cause stain or even decay. Also, in Ghana most timber is sawn in the green stated. Thus the moisture content of wood limits its use and energy yield. M.C. of wood residues is an important factor influencing the design of many of the conversion technologies used for energy production (Crisp, 1999). It is therefore important to know the exact moisture content of the species.

2.1.1. DEFINITION

The moisture content of wood is defined as the quantity of water in the wood expressed as a percentage of the wood weight in its wet or dry basis.

Moisture content on wet basis, MC_{wb} is defined as

$$MC_{wb} = \frac{W_{H_2O}}{W_{dw} + W_{H_2O}}$$

Moisture content on dry basis, MC_{db} is defined as

$$MC_{db} = \frac{W_{H_2O}}{W_{dw}}$$

Where W_{H_2O} is the inherent water

W_{dw} is weight of dry wood

2.1.2. MOISTURE CONTENT DETERMINATION

2.1.2.1. Methodology

Accurate weight of sample is put in pre-weighed tray and dried in an oven at 105^{0c} till constant weight. The sawdust was picked at the log yard during cross cutting of logs with chain saw. Moisture content of some selected species is given in table 1.

Table 1: Moisture content (Wet basis) of some selected wood species sawdust and bark

Species	**Mean Moisture content (%) (Wet basis)**	
	Sawdust	***Bark***
Triplochiton scleroxylon	43.90	53.39
Antaris toxicaria	41.76	59.19
Ceiba pentandra	60.00	40.02
Pterygota macrocarpa	42.72	40.30
Guibourtia ehie	48.76	32.04
Pycnanthus angolensis	47.75	56.83

2.1.2.2. Analysis

Wood at the time of logging generally has a moisture content of approximately 50 to 55 percent, although the amount varies according to species, age and the portion of the tree from which it originated, i.e. branches, trunk, etc. The values of the moisture content reported in Table 1 indicate that the logs had been in the log yard for a couple of days. It can be observed that moisture contents of the bark of *Triplochitoa, Antiaris,* and *Pycnanthus* were higher compared to *Ceiba, Guibouritia* and *Pterygota* due to the thickness of the bark of the former compared to the latter. Further fluctuations from the mean are influenced according to the season it is cut and the manner in which it is transported to the mill site and stored. Logs that are road-hauled and dry-debarked would be in order of 45 to 50 percent moisture content.(Pinchot, 2003) The moisture content of the manufacturing residues depend very much on the stage of the process they are extracted and whether there has been any drying of the product before that stage. For instance, sanding dust from plywood or particleboard manufacture is taken from the plant after the driers and hot presses, where its moisture content could be as low as 10 percent or less.

Although wood may be burnt at 55 percent m.c., and up to 58 percent m.c. with careful operator attention and boiler tuning, it is always better to aim for a moisture content of 50 percent or lower in order to achieve satisfactory and substained operation. When the moisture content rises to 60 percent, burning of the wood residues become difficult as its heating value drops dramatically, to the extent where, at approximately 68 percent m.c., "furnace blackout" occurs, being the point at which combustion can no longer be sustained, unless a supplementary fuel is used to maintain combustion.

A high moisture content not only lowers the as-fired heat value of wood waste, but seriously affects the overall combustion efficiency due to the large amount of energy needed to heat considerable quantities of excess air and to vaporize the moisture in the waste, which, together with the moisture formed by the combustion process itself is subsequently lost up the stack as latent heat.

The moisture content of sawdust in the mills is often above 70% (Wet basis) due to the sawing practice of using water spray to lubricate the saws. Sawdust from out-door heaps may have still higher moisture content. For energy generation it is desirable to use wood with low moisture content because the loss due to evaporation of the wood moisture is considerable. (Ahiataku, 1998)

2.2. ASH CONTENT

The inorganic mineral content in the wood that remains in oxidized form after complete combustion is called ash. The ash content of the wood and the ash composition has a major impact on a trouble free operation of a boiler and therefore the ash must be removed regularly. If this is not removed it can cause serious technical problems such as blocking of tubes of the boiler (FAO, 1988). However, modern cogeneration systems have automatic de-ashing units with all transfer conveyors, which take care of this problem.

2.2.1. ASH CONTENT DETERMINATION

2.2.1.1. Methodology

Table 3. TYPICAL WOOD CHEMICAL COMPOSITION (WEIGHT IN % IN DRY BASIS)

ELEMENT	COMPOSITION %
Carbon	44-51
Hydrogen	5.5-6.7
Oxygen	41-50
Nitrogen	0.12-0.06
Sulphur	0.0-0.2

Source: Thermo chemical conversion of Biomass to Energy, BTG. 1987.

2.4. ATOMIC ABSORPTION (AAS) ANALYSIS OF ASH.

2.4.1. Methodology

The ash of the selected wood species were weighed and digested with aqua regia, diluted with distilled water and presented for AAS reading. The results are shown in Fig 1 - 4

2.4.2. Analysis

From fig 1 and 2 it can be seen that the iron content is high for both the bark and the debarked wood for all the species. The lead content of bark is almost of the same level as that of the debarked wood.

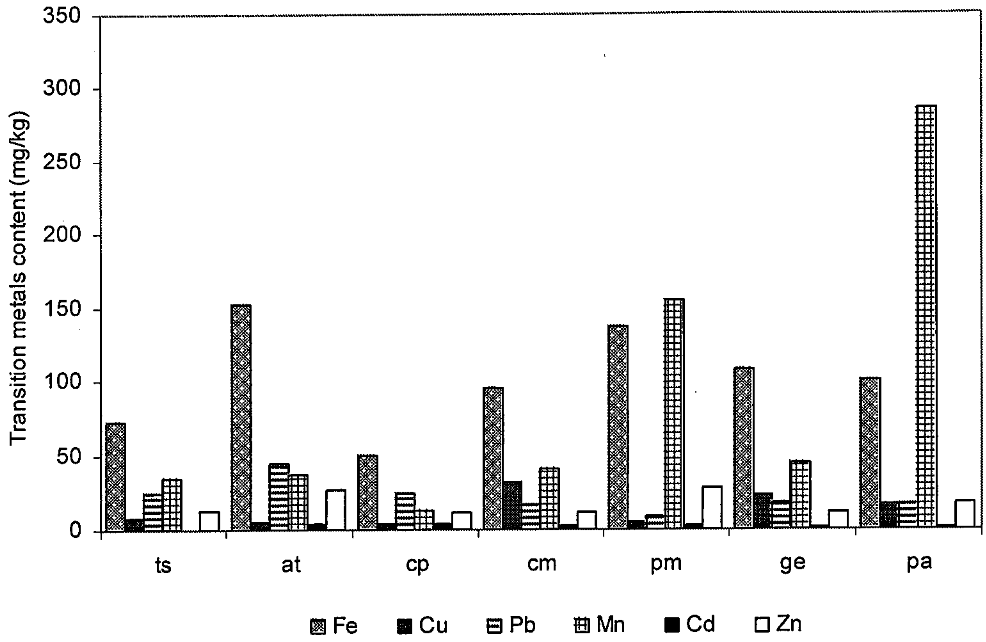


Fig. 1: Transition metals content of ash of bark of some selected wood species

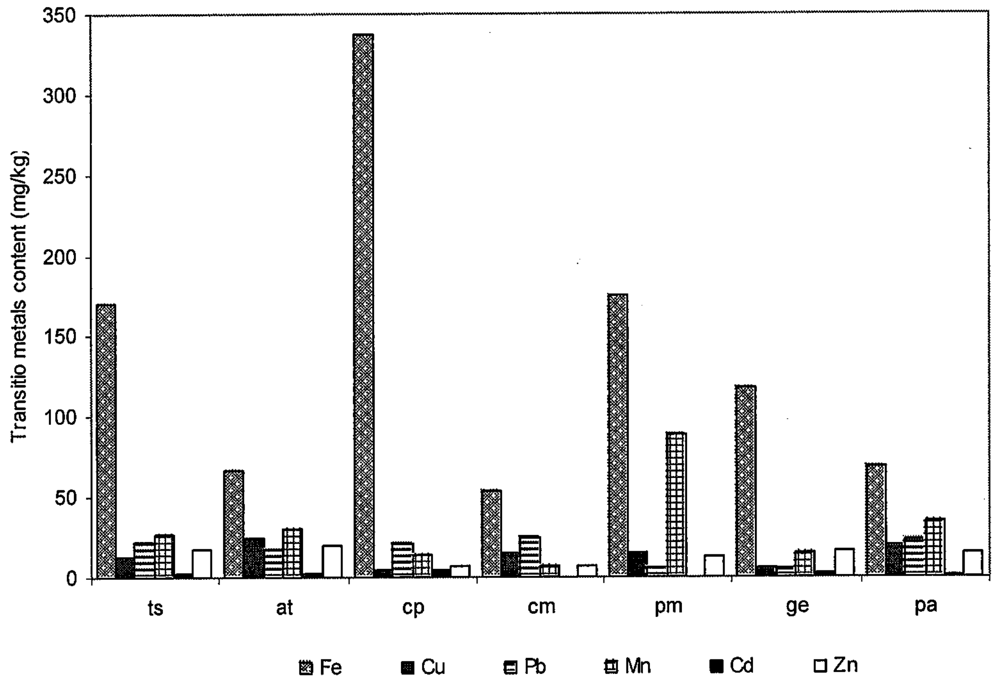


Fig. 2: Transition metals content of ash of wood of some selected wood species

pa-*Pycanthus angolensis*, ts-*Triplochiton scleroxylon*, cp-*Ceiba pentandra*, at-*Antiaris toxicaria*, cm- *Cordia millenii*, pm- *Pterygota microcarpa*, ge- *Guibourtia ehie*

From fig 3 and fig 4 it can be observed that the bark of all the species studied contain higher amount of calcium than the debarked wood except *Pterygota macrocarpa.* Similarly, potassium content of the bark is higher than the debarked woods of all the species studied. Sodium content is low for both bark and debarked wood of all the species.

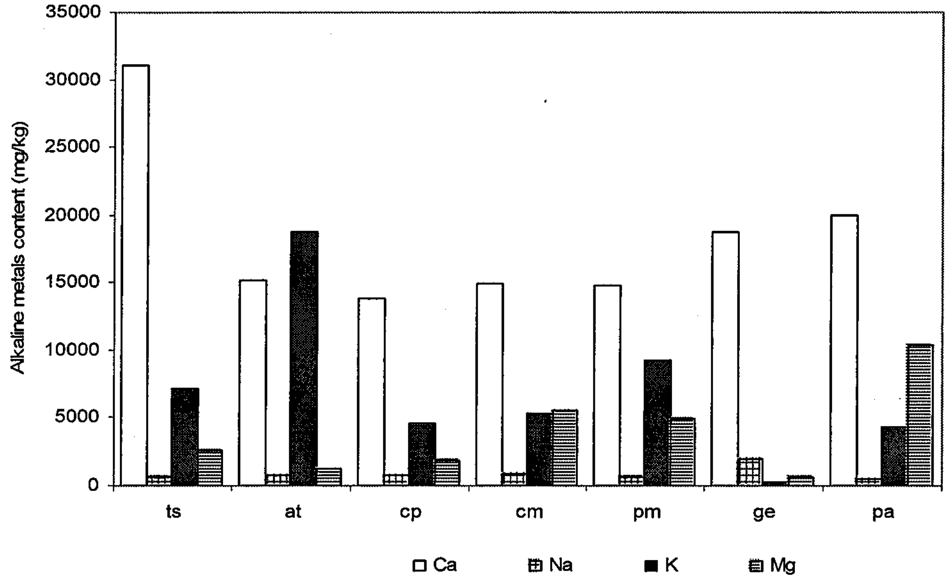


Fig. 3: Alkaline metals content of ash of bark of some selected wood species

pa-Pycanthus angolensis, ts-Triplochiton scleroxylon, cp-Ceiba pentandra, at-Antiaris toxicaria, cm- Cordia millenii, pm- Pterygota microcarpa, ge- Guibourtia ehie

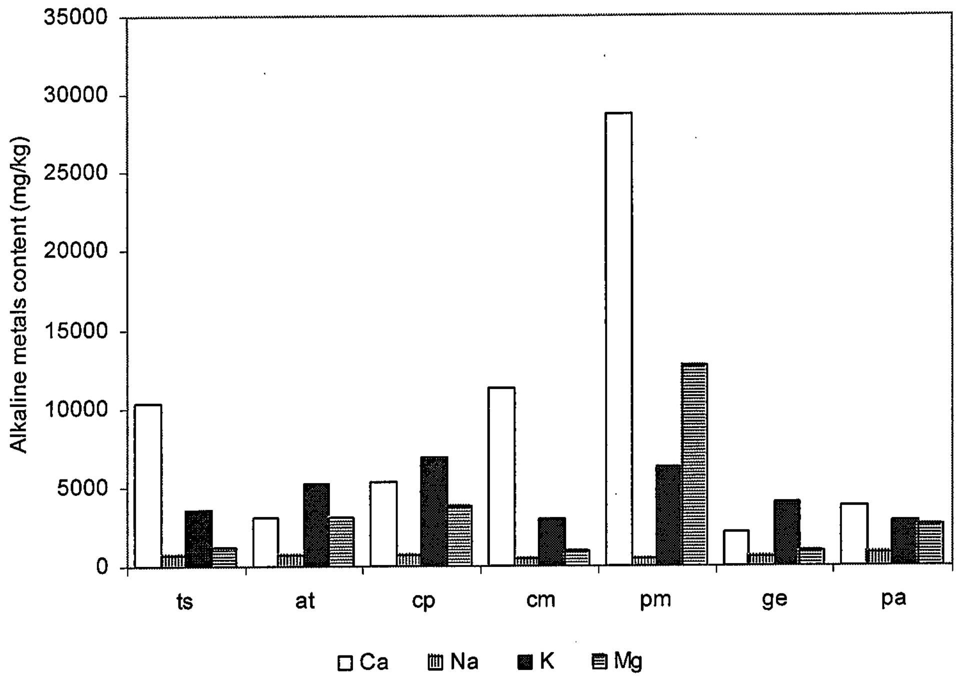


Fig. 4: Alkaline metals content of ash of wood of some selected wood species

pa- Pycanthus angolensis, ts-Triplochiton scleroxylon, cp- Ceiba pentandra, at- Antiaris toxicaria, cm- Cordia millenii, pm- Pterygota microcarpa, ge- Guibourtia ehie

2.5. BULK DENSITY (FUEL DENSITY)

Bulk density is the volume occupied by a certain amount of stored solid fuel. This is important to calculate the storage capacity for the co-generation system. The bulk density depends on the density and moisture content of the fuel particles, as well as the partial size and the piling (loosely or compacted)

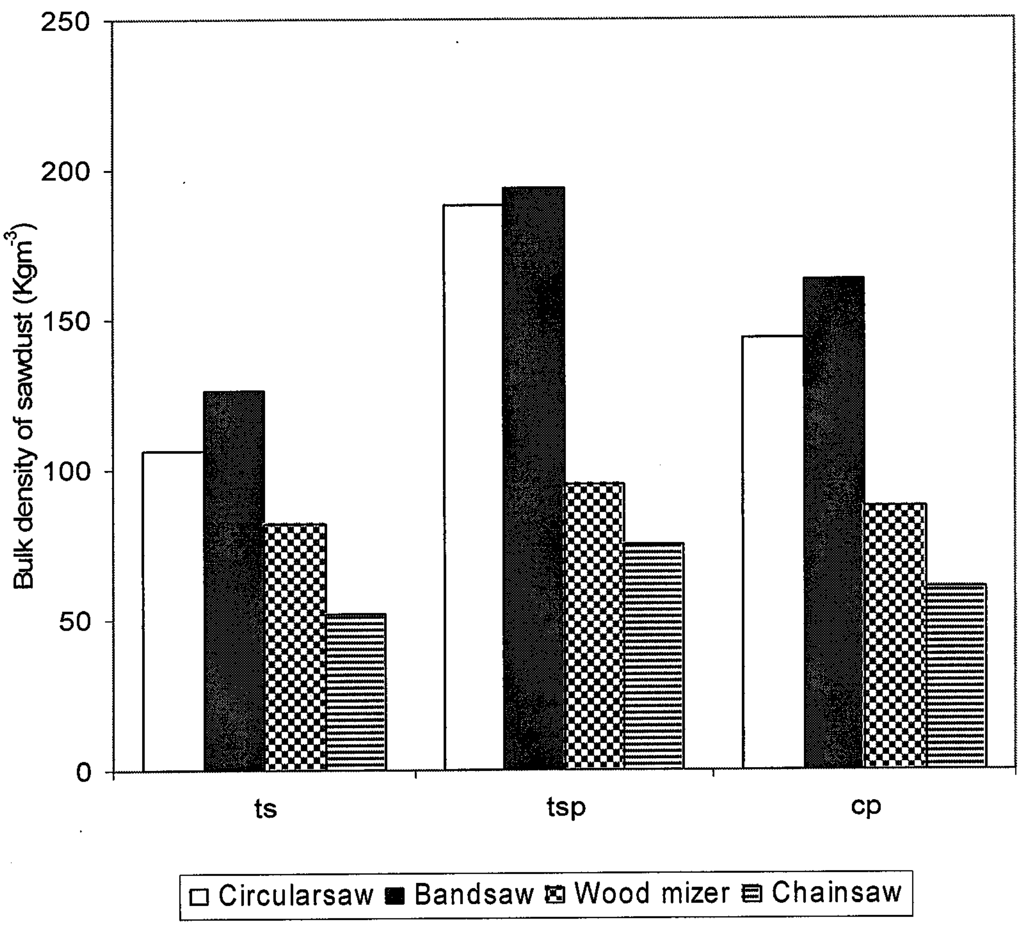
Fuels with high bulk density are advantageous because they have higher energy content per unit volume. Consequently, this fuel needs less bunker space for refuelling time. Low bulk density fuels sometimes give rise to insufficient flow under gravity, resulting in low gas heating values. Inadequate bulk density fuel can be improved by briquetting or palletising.

2.5.1. Methodology

Two cubical boxes of dimensions 10cm and 15cm were constructed. The sawdust of the selected species was air dried for 15 days with a temperate of 29^{0c}. Each of the boxes was filled to capacity with sawdust collected from cutting the wood with circular saw, wood Mizer, band saw and chain saw. The results are shown in Table 4

2.5.2. Analysis

Fig 5: Mean bulk densities of sawdust produced with circular saw, band saw, wood mizer and chain saw from selected wood species



ts- *Triplochiton scleroxylon*, tsp- *Terminalia superba*, cp- *Ceiba pentandra*

From Fig 5, it can be observed that of the three species used for bulk density studies *Terminalia superba* had the highest values for the various types of sawdust produced with different type of saws. Since the bulk densities varied for the three species for each of the saws it can be argued that the particles of each of the species differ.

However, it should be noted that the size and form of the wood particle is also critical in both the handling characteristics and burning efficiency of residues and plays a major role in their combustibility and the selection and operation of processing and combustible plant. Thus all steps taken to reduce the size of the residues to a minimum pays dividends in energy generation. Wood industries work on a lot of different species. These species are processed on the same production lines without normally removing the residues produced. Thus the sawdust produced would be a mixture of different species which as shown in Fig 5 would have differing bulk densities.

2.6. HEATING VALUE OF WOOD

When evaluating the properties of combustible material with respect to its use as a fuel, the heating value is one of the most importance factors which indicates the amount of thermal energy which may be obtained be combusting one mass unit of the material.

The energy content of wood is determined by its heating value. Heating values are classified as:-

(i) Higher heating value (HHV)

(ii) Lower heating value (LHV)

The higher heating value of fuel is the total heat liberated in kilojoules per kilogram or cubic metres. The lower heating value is the energy content per kilogram or cubic metre after the heat of water of vapourization has been deducted. The amount of heat wood residue gives off when it is burnt is largely dependent on its moisture content (Crisp, 1999). Energy yield is usually expressed as its net calorific value which will increase as the wood moisture is reduced(Fordyce and Ensor, 1982).

The heating value of wood depends very much on the species and part of the tree being used and varies between 17 to 23 MJ/kg of bone dry wood (Nketia et al 1988). Although the fuel value may be fairly consistent in bone dry wood, the heating values depend on several factors, namely moisture content, particle size, type and efficiency of combustion equipment being used and the level of its operation and maintenance (Mace).

2.6.1. Determination of heating values

2.6.1.1. Methodology

Bomb calorimeter was used. The solid fuel (wood) was crushed, passed through a sieve and then pressed into the form of a pellet in a special press. The sample was then dried in a furnace and its moisture content determined. The measured temperature rise was corrected for various losses. The cooling loss was the largest but corrections were made for the heat released by the combustion of the wire itself. The cooling corrections were determined by the Regnault and Pfaunder, formula. HHV and LHV were determined for 13 selected hardwood species.

The results are shown in Fig 6 & 7

Accurate weights of the samples were ashed in the furnace at 650^0C for 4 hours. The mass of ash was weighed after cooling. The residual mass (ash) was deducted from the initial wood mass. The results of ash content of some selected species are given in table 2.

Table 2: Ash content of some selected wood species.

Species	**Ash content (%)**	
	wood	Bark
Triplochiton scleroxylon	4(1.3)	8
Antaris toxicaria	2(2.9)	14
Ceiba pentandra	4(3.2)	6.00
Cordia pentandra	2.26	2.54
Pterygota macrocarpa	3.98	10.12
Guibourtia ehie	1.35	9.58
Pycnanthus angolensis	2.93(3.6)	10.00

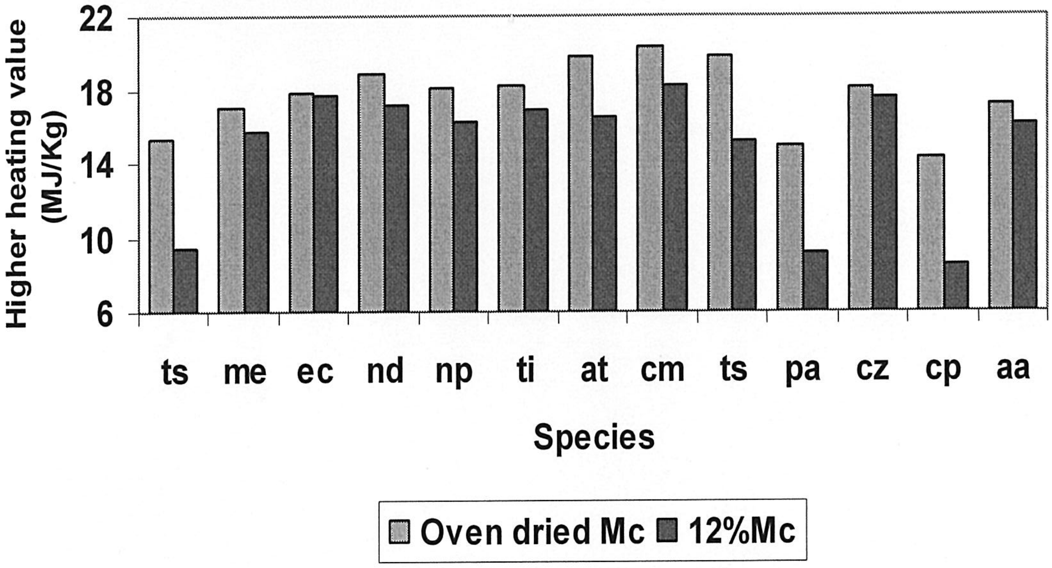
2.2.1.2. Analysis

Table 2 shows that the ash content of debarked wood is less than that of the bark. Probably the high ash content of the bark helps to protect the wood from decay fungus and insects. This also explains why bark is not a preferred material to use in boiler for energy generation.

2.3. COMPOSITION

Wood residue consists of an organic fraction, an inorganic fraction and water. The organic fraction consists of carbon, hydrogen and oxygen. A small amount of nitrogen and sulphur are also present but almost insignificant. It is the organic fraction that is combusted although the inorganic component does influence the combustion process and it is termed ash, a solid residue remaining after combustion. The composition of the ash free organic component of wood is relatively uniform. Table3 represents the chemical composition of wood fuel.

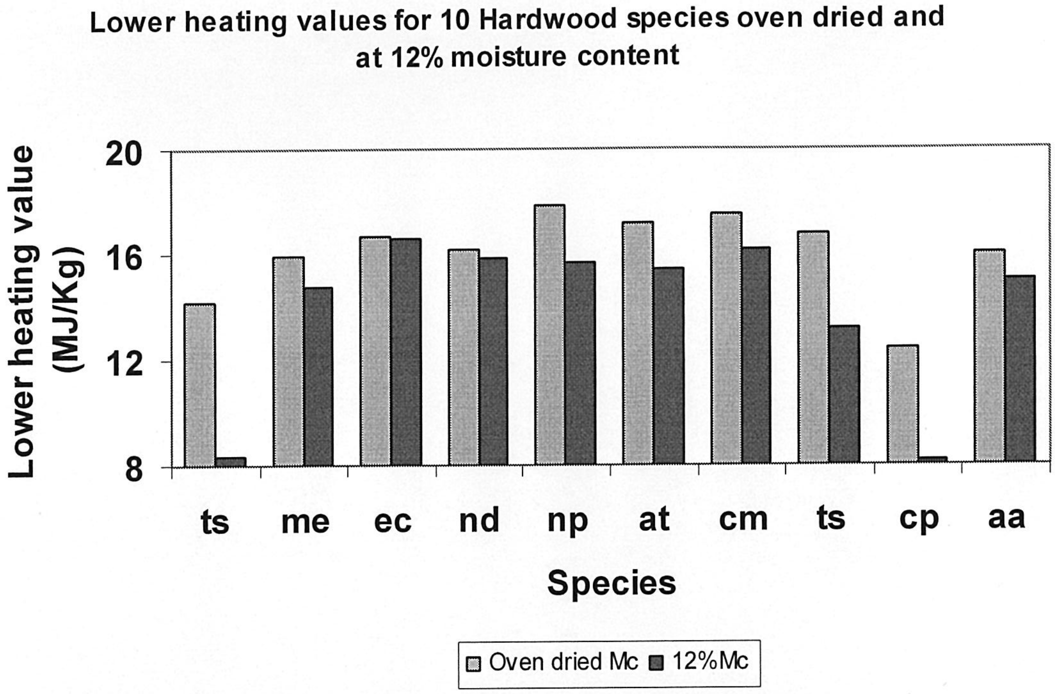
Fig 6: Higher heating values for 13 Hardwood species at oven-dried and at 12% moisture content



ts-*Triplochiton scleroxylon*, me-*Milicia excelsa*, ec-*Entandrophragma cylindricum*, nd-*Nauclea diderrichii*, np-*Nesogordonia papaverifera*, ti- *Terminalia ivorensis*, cm-*Celtis mildbraedii*, ts- *Terminalia superba*, pa-*Pycanthus angolensis*, cz-*Celtis zenkeri* cp-*Ceiba pentandra*, aa-*Afzelia africana*, at-*Antiaris toxicaria*

2.6.1.2. Analysis

From fig 6 and 7 it can be observed that *Ceiba pentandra* had HHV and LHV of 14.2 MJ/kg and 12.4 MJ/kg for oven-dried wood respectively. This was the lowest value among the 13 species whose HHV were determined. This also explains why boiler operators are not keen to use residues from Ceiba. Apart from Ceiba having low HHV it moisture content is also very high, (Table 1). It can be observed that the oven-dried wood HHV and LHV of the wood species are fairly constant. The values decrease as the moisture content increases (Mace).



ts-*Triplochiton scleroxylon*, me-*Milicia excelsa*, ec-*Entandrophragma cylindricum*, nd-*Nauclea diderrichii*, np-*Nesogordonia papaverifera*, cm-*Celtis mildbraedii*,
ts- *Terminalia superba*, cp-*Ceiba pentandra*, aa-*Afzelia africana*, at-*Antiaris toxicaria*

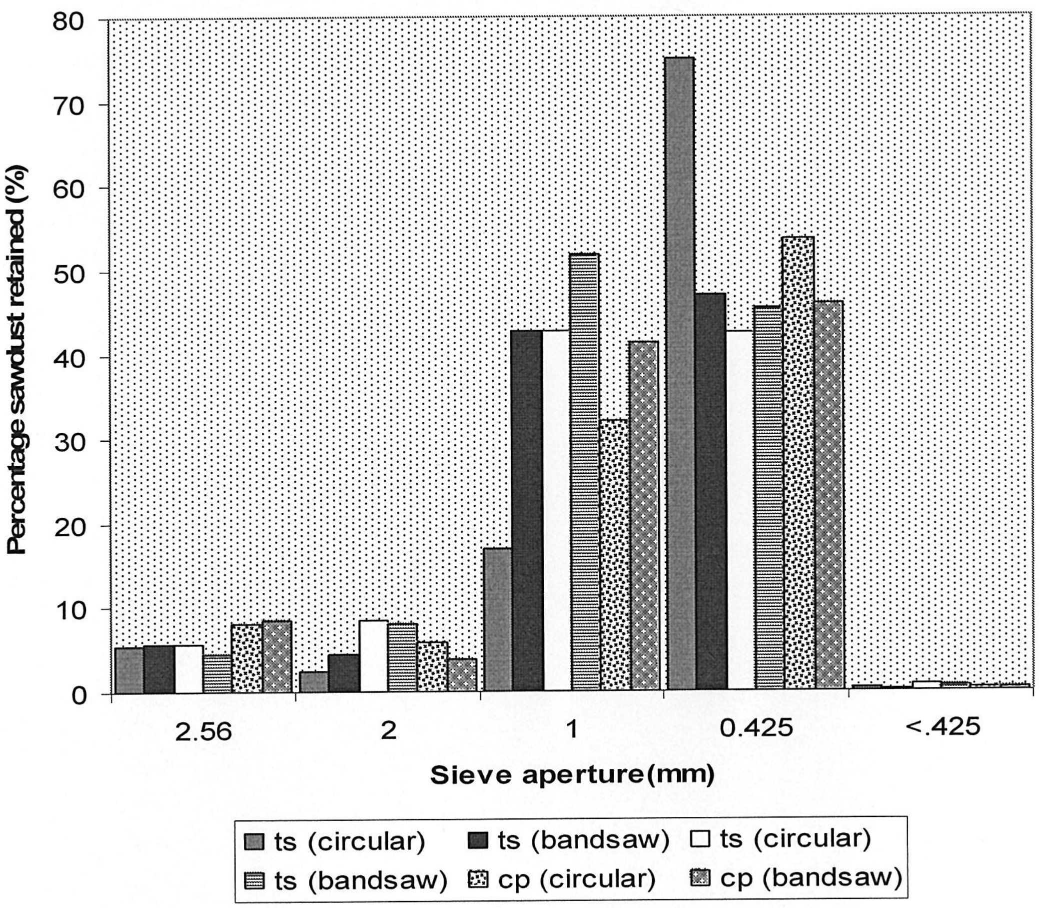
2.7. SIZE OF PARTICLES OF SAWDUST

2.7.1. Methodology

Sawdust was collected from a sawmill. It was collected from three logs of the same species when they were being sawn. It was air-dried for three weeks in the laboratory. It was sieved with sieves of different apertures as shown in Fig 8. For each of the species 988g of sawdust was weighed and separated into different portions. The portions which were retained on the sieves after shaking were recorded.

2.7.2. Analysis

Fig 8: Percentage weight of sawdust retained on sieves using circular or bandsaws on various species



From figure 8, it can be observed that the percentage of the sawdust that was retained by 2.56mm sieve was less than 10% whether bandsaw or circular saw is used for the cutting. The percentage retained when circular saw was used did not very significantly from species to species. When band saw was also used for cutting the percentage of sawdust retained on 2.56mm sieve was about 10% for *Ceiba pentandra* and *Terminalia superba* but was about 4% for *Trplochiton scleroxylon.*

This indicated that when circular or bandsaw was used to saw a log particles larger than 2.00mm were not appreciable in the sawdust produced. Most of the particles of sawdust produced from circular or bandsaw sawing were less than 2.00mm in size. Particles of less than 0.425mm were less than 0.5%.

Similarly the percentage of sawdust retained on 2mm sieve for the three species was less than 10% for circular saw and band saw. The percentage that are retained on 1mm and 0.425mm sieves are between 20 and 75%. This gives an indication that the size and forms of the wood particles are also critical in both handling characteristics and burning efficiency of residues and plays a major role in their combustibility and the selection and operation of processing and combustion plant.

3. AVAILABILITY OF WOOD RESIDUE

Photo: Residues dumping ground.

The wood residues that are produced from Ghanaian woods could be grouped into two:-

(i) Residues left on the forest floor after extraction of logs comprising stump, crown and ends as well as defective logs.

(ii) Residues generated during the processing of logs in the mill comprising sawdust, bark, off-cuts slabs, trimming, veneer waste and veneer core.

3.1. Data from Asuo Bomosadu Timbers and Sawmaill Ltd (ABTS)

Asuo Bomosadu Timbers and Sawmaill Ltd is situated at Berekum in Brong Ahafo Region of Ghana. It produces lumber, veneer and plywood for local and international markets. In addition to the product mentioned above it also produces flooring parquet and flooring strips for export.

The estimated monthly log input is 6000m^3 out of which 2,500m^3 is for sawing and 3,500m^3 is for veneer production.

The generalized species mix is as follows:-

(i)	*Ceiba pentandra*	-	65%
(ii)	*Triplochiton scleroxylon*	-	15%
(iii)	*Milicia excelsa*	-	5%
(iv)	*Terminalia superba*	-	10%
(v)	Red woods	-	4%

(vi) Others - 1%

Of the log inputs 12%, 20%, 17%, and 50% are sawdust, off-cuts, slabs and edgings and lumber respectively.

Photo: Log ends being burnt in the open-air

photo: Slabs ready to be sold.

For the rotary cut, the veneer core and defective sheet each constitute 20%.

20% of the slabs and edgings are reprocessed, whilst 10% is sold as such. 80% of the sawdust is fed to the boiler.

To fully utilize the processing residues for fuel (boiler-feed), the mill will require a hogger to chip the residues.

Currently, the company has fuelwood depots in the forest to harvest branches and other forest residues for fuel (boiler). Six (6) tipper truck loads are received per week from their own forest operations. Another four truck loads are bought from outside suppliers.

3.1.1. Wood residue utilization

Flooring parquet is produced from the following species: *Milicia excelsa*, *Afzelia africana* and *Guibourtia ehie.*

Flooring strips of 10mm x 15mm x 250mm are also produced from species like *Milicia excelsa*, *Tectona grandis*.

Photo: Residue utilization for flooring parquet

Triangular mouldings (10mm x 10mm x 10mm x 2.5m) are also recovered from *Triplochiton scleroxylon* and *Ceiba pentandra.*

3.1.2. Average recoveries

From primary processing stage there is 30% recovery with 12% sawdust; 20% of the residues (solids) are for secondary processing of which 10% comes off sawdust.

Residues that are not reprocessed include slabs, bark, sapwood edgings, and defective material. Altogether these constitute are about 38% of the initial log input.

3.2. Data from Logs and Lumber Limited

The mill has two production lines for the lumber production section. In addition to these it has a sliced veneer section and rotary veneer section. The workers operate 2 shifts of 12 hours each with one hour rest period.

From 2nd January 2004 to 31st January 2004 the logs input and processing were studied. The monthly log input volume during the period was 7,152.024m^3.

Out of this volume.

(i) 1,933.353m^3 was for sliced veneer production;
(ii) 1,673.962m^3 was for plymill production; and
(iii) 3,544.709m^3 was for sawmill (lumber) production.

The total number of logs from which the total volume of 7,152.024m^3 was obtained, were 1,021. The wood species from which the sliced veneer were produced were:-

(i) *Antiaris toxicaria*
(ii) *Aningeria altissima*
(iii) *Khaya ivorensis*
(iv) *Entandrophragma angolense*
(v) *Pterygota macrocarpa*

For logs of total volume 129.892m^3 the total volume of bolts was 103.716m^3 while flitch total volume was 96.25m^3. Total sliced veneer produced from the logs was 42.516m3. The off cuts were 20.16% while slabs and edgings were 7.2%. slicer rejects (Defective veneers) were 55.86% Total sliced veneer recovery was 32.73%

Rotary veneer and plywood production

The wood species for rotary veneer and plywood production were:-

(i) *Pycnanthus angolensis*
(ii) *Terminalia superba*
(iii) *Pterygota macrocarpa*
(iv) *Antiaris toxicaria*
(v) *Celtis zenkeri*
(vi) *Cebia pentandra*

Ceiba constituted 50% of the total logs input and *Pterygota macrocarpa* 30% and the other species 20%.

Sawmill production

The generalized species mix for the sawmill were

(i) *Triplochiton scleroxylon*
(ii) *Terminalia superba*
(iii) *Pterygota macrocarpa*
(iv) *Cylicodiscus gabunemsis*
(v) *Khaya ivorensis*
(vi) *Milicia excelsa*

Tripochiton scleroxylon constituted 75% of the total log inputs and the others 25%. Generally the average recovery (export) for the sawmill section was 31.44% and lumber reject was 18.12%. Off cuts, slabs edgings and sawdust were 51.44%.

3.2.1. Recovery and wood residue generation

The average recovery rate of the slicer is 31.6%. Thus for the period of study the monthly recovery was 610.939m^3. The residue for the period was 1,322.414m^3.

The rotary veneer and defective veneer residue generation constituted about 44% of the log input. The off-cuts from rotary plywood production constituted about 16%. The defective rotary veneer was 21% and the core was 23% of the total log inputs.

Photo: Veneer core at dumping site

Table 6: Daily input & output volumes and % wood residue generation.

Species	**Input vol.(m^3/)**	**Export vol (m^3)**	**Lumber rejects**	**Offcuts, slabs & sawdust**	**Recovery (export)**
Pterygota macrocarpa	77.984	23.736	9.544 (12.23%)	57.34%	30.43%
Entandrophragma angolense	35.832	11.507 (31.95%)	11.451	35.93%	32.11%
Triplochiton scleroxylon	76.916	27.673 (4.68%)	3.602	59.34%	35.97%
Milicia excelsa	39.062	6.907	7.653 (19.54%)	53.15%	27.26%

3.3. Oda Sawmill and Plywood Limited

Oda sawmill and Plywood Limited is located at Akim Oda in the Eastern Region of Ghana. Formerly it was a vibrant mill but now it has become a shadow of its former glory. This is due to the absence of concession for harvesting of timber species. Now the mill has to purchase all its logs from other concessions in the Region.

The company operates sawmill and plymill sections. The main products from the company include lumber, tongue and groove (T&G) and plywood.

3.3.1. Processing activities

3.3.1.1. Sawmill Section

The general species mix for the entire mill include:

(i) *Cylicodiscus gabunemsis*
(ii) *Cistanthera papaverifera*
(iii) *Piptadenia africana*
(iv) *Triplochiton scleroxylon*
(v) *Terminalia ivorensis*
(vi) *Terminalia superba*

Table 7: Log input for 2 months (volume, m^3) for the sawmill section

Species	Volume of logs (m^3)	
	January	**February**
Ceiba pentandra	98.098	1046.966
Cylicodiscus gabunensis	79.312	-
Piptadenia africana	20.503	3.734
Terminalia ivorensis	2.527	-
Terminalia superba	3.816	-

The total volume of log input was 1084.259m^3 and the output was 325.277m^3 or 30%. This was the volume exported. For the local market the volume was 166.2m^3 or 15.3%. The residue generated during the processing in the form of slabs, edgings, off-cuts, and sawdust was 622.36m^3 or 52% of the total log input.

3.3.1.2. Plymill section

Table 8 The total number of logs processed in January and February 2004

Month	Number of logs	Volume of logs (m^3)
January	143	1062.867
February	153	1067.197

The total output of plywood and veneer was 45% of the input logs. Thus the veneer core, edgings and defective veneer totalled 55% of the total log input. (Table 8)

3.4. Omega wood processing mill Ltd

This mill is in Kumasi. It produces lumber, veneer and plywood for domestic and international markets. From Table 9, it can be observed that the average monthly log input was 4007.567m3 for rotary veneer and plywood production. The monthly average recovery was 1420.829m3 or 35.45%. The total volume of wood residue from the total log input was 2586.708m3 or 64.54%. The total monthly average volume of bark, sawdust and off-cuts were 966.730m3 or 24.12%. The total monthly average volume of residue (veneer core, trimmings and defective veneer and plywood) from the production line was 1617.979m3 or 40.37%.

3.4.1. Processing activities

3.4.1.1. Plymill section

Table:9 the monthly log input for veneer and plywood production and residue generation for 7 months

Month	Total log vol m^3	Total vol of bolts & flitches from log inputs	Total vol of veneer and plywood	Total vol of residue from production line	Total vol of bark, off cuts and sawdust	Volume of wood residue from total input	Percentage of total residue of log input (%)
Jan	5198.97	2838.97	1745.95	2150.53	1302.31	3453.03	66.54
Feb	4056.28	3028.08	1442.64	1562.11	1052.21	2613.64	64.43
March	3307.03	3896.48	1138.98	1415.84	752.22	2168.05	65.61
April	3925.09	3004.72	1557.21	1452.53	915.45	2367.88	60.33
May	4623.17	2554.82	1630.91	1921.24	1071.41	2992.27	64.72
June	3204.67	3009.72	1024.42	1417.32	762.90	2180.25	68.01
July	3708.48	3552.14	1364.14	1474.83	869.51	2344.33	63.20

From table: 9, the average monthly log input was 4003.37m^3 for rotary veneer and plywood production. The monthly average recovery was 1165.61m^3or 35.45%. The total volume of wood residue from the total log input was 2588.71 m^3or 64.54%.The total monthly average volume of residue (veneer core, trimmings and defective veneer and plywood from the production line was 1627.77m^3 or 40.35%

3.4.1.2. Sawmill section

Table 10 gives the log input as 6717.619m3 from the sawmill for lumber production for seven months.

Table:10 Total log inputs by species, lumber recovery and residue generation

Species	Total Input (m^3)	Total Output (m^3)	Total Yield (%)	Total Residue (%)
Trplochiton scleroxylon	7988.992	3099.320	38.795	61.205
Terminalia superba	600.647	130.138	21.800	78.167
Terminali ivorensis	74.561	15.394	20.646	29.354
Milicia excelsa…	66.368	15.308	23.065	76.935
Nesogordonia papaverifera	5.118	0.118	2.305	97.694
Entandrophragma cylindricum	40.781	7.778	19.073	80.927
Pterygota macrocarpa	15.456	8.500	54.995	45.005
Entandrophragma utile	21.672	4.067	18.766	81.234
Entandrophragma angolense	19.434	2.546	13.100	86.899
Khaya ivorensis	12.603	0.892	7.078	92.922
Aningeria altissima	45.984	13.056	28.000	71.608
others	6.021	2.352	39.063	60.937

From table 10, in the primary processing stage, there was an average of 23.89% recovery with estimated 12% sawdust. The total residue generated was 71.90% out of which an estimated 20% went into secondary processing; generating an estimated 10% sawdust from the residues.

It can be seen from the total log input of *Nesogordonia papaverifera* of 5.118m^3 the residue generated was 97.694%. This gives as indication of the physical outlook of the log in terms of straightness, extent of decay, bend etc.

Photo: Residue ready for boiler.

Photo: mixed residue being burnt in the open-air

Table 10 give the log input as 8897.637 m3 from the sawmill for lumber production. The generalized species mix is as follows

Trplochiton scleroxylon 89.78%
Terminalia superba..6.75%
Terminalia ivorensis.. 0.84%
Milicia excelsa.. 0.75%
Aningeria altissima.. 0.52%
Entandrophragma cylindricam..0.46%

Pterygota macrocarpa..0.17%
Entandrophragma utile..0.24%
Entandrophragma angolense..0.22%
Khaya ivorensis... 0.14%
Cistanthera papaverifera..0.06%
Others.. 0.068%

4. CLASSIFICATION OF WOOD RESIDUE

4.1. Types available

The main forms of residue identifiable in the mills are sawdust, slabs, edgings trimmings, barks, off-cuts and veneer core. The secondary process which is practised by only a few mills produces mainly sawdust and wood shavings

Photo: bark at dumping site

4.2. Quantities of Wood Residue Available

According to the work done by Ben-Dzam and Hagan (1987), It was found that about 164,516m3 of solid wood waste was generated by some selected sawmills. The residue included slabs, edgings, trimmings, and off-cuts and were sold as firewood and for charcoaling.

They saw that only a few integrated mills made use of the residue they generate for the manufacture of the value added products such as knock – down furniture components and mouldings.

Their study showed that out of the nineteen sawmills surveyed, those which utilized their residue used about 43% of the residue generated (approximately 66,887 tonnes) out of a total of 156,538 tonnes generated annually.

In 1988, Ofosu – Asiedu *et al* made the following volumetric estimates of annual residue production:

Slabs and edging	229,294 m3
Off-cuts	84,541m3

Sawdust	108,747 m3

These estimates show that on the average as much as 55% of the total log input in primary processing comes out as waste or residue.

Current studies have shown that the percentage wood residue of log inputs is as follows:

Sawdust	12%
Off-cuts	20%
Slabs and edgings	17%
Rotary veneer residue & defective veneer	21% & 23% respectively
Off-cuts from rotary plywood production	16%.

5. CONCLUSION

Energy is still the largest and the dominant use made of wood and it will remain the largest single use for the foreseeable future. Hence the study has provided an assessment of some of the important parameters of wood residue necessary to determine its suitability for energy generation and also has provided information on the volume of wood residue available in the processing mills. The wood processing mills generate large volume of wood residue during production process. The wood residue generated include, sawdust, shavings, trimming, slabs, veneer core, defective veneer, edgings, off –cuts and barks. There is a trend towards increased use of sawdust as a boiler feed. A substantial portion of the residue is reprocessed into useful products such as flooring parquets, flooring strips and triangular moldings. The study has also revealed that the preferred timbers species are no longer available and the processing mills are relying more on the lesser used species. Again, it has come to the fore that recoveries of export products are still very low.

The mills selected were Asuo Bomosadu Timbers and Sawmills Limited (ABTS LTD), Log and Lumber Limited (LLL) and Omega Wood Processing Limited (OWPL) which have annual wood residue of about 27,360 m^3, 32,610 m^3 and 19,230 m^3 respectively.

6. RECOMMENDATION

Suggested areas where further work could usefully focus include:

1. Critical assessment of available residues
2. Critical study of technical options
3. Identification of optimal use-options
4. Socio-economic analysis of the various options
5. Critical study of the efficiency in the industry
6. Value addition vis-à-vis specialization

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