Estimation Of The Thermochemical And Solubility Properties Of Some Nigerian Softwood

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Abstract: The abundance of softwoods in Nigeria makes them readily available and their renewability is also an advantage in generation of any product that has usefulness in scientific application. All the softwood samples investigated were soluble in hot concentrated H_2SO_4. From a measured quantity of each Nigerian softwood powder consumed in their destructive distillation, the results showed that: *Tetrapleura tetraptera* had appreciable quantities of wood charcoal with a maximum value of 5.2g, *Allanblackia floribunda, Afzelia bella* and *Afrormosia laxiflora* each with 4.5g also had high quantities of wood charcoal. *Afzelia bipindensis, Cassipourea barteri* and *Khaya ivorensis* each produced 3.00cm^3 pyroligneous acid volume. Tar volumes of 0.25cm^3 as the highest value was observed in each of *Monodara tenuifolia, Anogeissus leiocarpus, Amphimas pterocarpoides, Afzelia bipindensis* and *Cassipourea barteri*. The volumes of wood gas emitted were high. The maximum wood gas emitted showed values of 998 and 980cm^3 from *Afzelia bipindensis* and *Sacoglottis gabonensis*. These thermochemicals have agricultural, industrial and domestic values.

Keywords: Solubility, Nigeria, softwood, chacoal, tar, wood gas, pyroligneous acid.

1. INTRODUCTION

Destructive distillation of woods produces distillates made up of vapours and gases as well as vapour condensates in form of tars in addition to charcoal. The thermochemicals derived from this century long process is used in production of various components useful in industrial goods and wood products. Pyroligneous acid is a waste gotten from chemical breakdown of wood by destructive conversion of wood liquid in oxygen deficient situation. During tar formation wood is gradually decomposed with heat to form an oily component which is separated from pyrolysis liquid by sedimentation [1]. Tiilikkala *et al*. [1] also explained that pyrolysis is a heat transformation reaction in which the material (wood) in oxygen deficient environment is combusted to end reaction at temperature of 500^{o}C. The end product is solid char comprising charcoal and biochar, others consists of liquid compounds which are volatile in nature as well as gases which are highly volatile. Wood ash is produced by recovery of residues from burnt wood and woody materials [2]. Wood burning gives between 6 to 10 percent of ashes. Ash is made up of mineral elements required for growth of plants [3]. Magnesium, Potassium and Phosphorus are found in good quantities in ash, however, calcium is the most abundant element in it. Ash is also a good repository of many trace nutrient needed for plant growth and development [3]. The importance of this research is to study the quantities of thermochemical constituents of some Nigerian softwood. This has industrial importance. Sources of chemical production as well as energy generation could be initiated from fast pyrolysis of wood biomass [4]. Therefore, “wood pyrolysis is attractive because forest and industrial wood residues can be readily converted into liquid products” [4]. There are lots of advantages in transport, storage, combustion, retrofitting and flexibility in production and marketing generally when wood pyrolysis such as crude bio-oil of charcoal of water or oil exists in liquid form [5].

2. MATERIALS AND METHODS

2.1. Materials

Twenty four soft wood samples were collected, identified and stored using the methodology previously reported by Ejikeme *et al*. [6].

2.2. Wood Sample Preparation

Twenty four well grounded fine powdered timber softwood samples were obtained and prepared for analysis [6].

2.3. Determination of the Products of Destructive Distillation of the Wood

Each boiling tube was filled with 6.00g of the individual Nigerian softwood powder, and the

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Figure 1: Experimental set up of the destructive distillation of the wood without the gas jar.

Figure 2: Experimental set up of the destructive distillation of the wood with gas jar.

apparatus was set up as shown in Figure **1** without gas jar and Figure **2** with gas jar. Each wood sample was heated for 10 minutes to drive away the air in the apparatus before connecting the gas jar. The wood sample in each boiling tube was heated for 2 hours in the absence of air and four different fractions of substances were obtained. The substances obtained were: wood charcoal, pyroligneous acid, wood tar (ethanol was used in the extraction of the wood tar) and wood gas [7]. The substances obtained were measured and weighed to determine their actual weight present in each wood sample.

2.4. Wood Solubility

The wood solubility was determined by the method reported by Ejikeme *et al*. [6].

2.5. Determination of Ash Content

This measures the mineral content of the wood samples. A weighed crucible was thoroughly washed, cleaned and placed in hot air-circulation oven for 2 hours and cooled to a room temperature in a desiccator. The empty crucible was then transferred to the muffle furnace to burn off all organic matter and also to stabilize the weight of the crucible at a temperature of 600°C after which it was cooled in a desiccator at room temperature. Some 5.0g of the wood powder was defatted with 150cm^3 of diethyl ether using soxhlet apparatus for 2 hours. Into the crucibles was weighed 2.0g of each defatted wood powder, placed in the muffle furnace and digested (ashed) at a temperature of 600°C for 3 hours. At end of the digestion, each ashed sample was transferred into a desiccator to cool at room temperature after which the crucible with its content was re-weighed [8]. The percentage ash content was calculated thus:

$$\%Ash = \frac{crucible\ and\ Ash\ -\ Weigh\ of\ Crucible}{Weight\ of\ sample} \times 100$$

3. RESULT

The softwood samples subjected to solubility in various solvents showed that all the wood samples had the same solubility properties. The result (Table **2**) showed that the softwoods examined were insoluble in hot and cold water, dilute and concentrated HCl, dilute NaOH, ethanol and diethyl ether. Heated concentrated HCl, dilute H_2SO_4 and concentrated H_2SO_4 gave

Table 1: Table of the Botanical and Local Names as well as Location of Various Nigerian Softwood

S/N	Wood Sample (Botanical Name)	Classification	Botanical families	Igbo Names	Yoruba Names	Hausa Names	Location
1.	*Monodara tenuifolia*	Softwood	Annonaceae	Ehuru ofia	Lakesin	Guyiyadanmiya	Port Harcourt
2.	*Moringa oleifera*	Softwood	Moringaceae	Okwe oyibo	Ewe igbale	Zogallagandi	Lagos, Ibadan
3.	*Protea ellilottii*	Softwood	Proteaceae	Okwo	Dehinbolorun	Halshena	Nsukka
4.	*Barteria nigritian*	Softwood	-	Ukwoifia	Oko	Idonzakara	Nsukka, Enugu
5.	*Anogeissus leiocarpus*	Softwood	Combretaceae	Atara	Egba	Marike	Onitsha, Awka
6.	*Allanblackia floribunda*	Softwood	Guttiferae	Egba	Orogbo	Guthiferae eku	Calabar, Ikom
7.	*Glyphea brevis*	Softwood	Tiliaceae	Anyasu alo	Eso, shishi	Bolukonu kanana	Calabar
8.	*Sterculia oblonga*	Softwood	Stericuliaceae	Ebenebe	Aworlwo	Kukuki	Ibadan
9.	*Uapaca guineensis*	Softwood	Euphorbiaceae	Obia	-	Wawan kurmi	Onitsha
10.	*Amphimas pterocarpoides*	Softwood	Leguminosae	Awo	Ogiya	Wawan kurmii	Umuahia, Iko
11.	*Albizia adianthifolia*	Softwood	Leuminosae-Mimosoideae	Avu	Anyimebona	Gamba	Enugu, Nsukka
12.	*Dichapetalum barteri*	Softwood	Dichapetalaceae	Ngbu ewu	Ira	Kirni	Onitsha, Agulu
13.	*Afzelia bipindensis*	Softwood	Fabaceae	Aja	Olutoko	Rogon daji	Benin
14.	*Afzelia bella*	Softwood	Fabaceae	Uzoaka	-	Epa	Owerri, Orlu
15.	*Dichrostacys cinerea*	Softwood	Fabaceae	Amiogwu	Kara	Dundu	Onitsha
16.	*Pentaclethra macrophylla*	Softwood	Leguminosae	Ugba	Apara	Kiriya	Onitsha
17.	*Tetrapleura tetraptera*	Softwood	Leuminosae-Mimosoideae	Oshosho	Aridan	Dawo	Onitsha, Akpaka
18.	*Afrormosia laxiflora*	Softwood	Leuminosae-papilionoideae	Abua ocha	Shedun	Idon zakara	Sokoto
19.	*Sacoglottis gabonensis*	Softwood	Rhizophoraceae	Nche	Atala	Chediya	Rivers
20.	*Cassipourea barteri*	Softwood	Lecythidaceae	Itobo	Itobo	Odu	Eket
21.	*Combretodendron macrocarpum*	Softwood	Ochnaceae	Anwushi	Anwushi	Akasun	Udi, Owerri
22.	*Cordial millenii*	Softwood	Meliaceae	Okwe	Okwe	-	Owerri, Onitsha
23.	*Khaya ivorensis*	Softwood	Bignoniaceae	Ono	Oganwo	Madachi	Calabar
24.	*Kaempferia galangal*	Softwood	Zingiberaceae	Shanty	-	-	Enugu

slight solubility when the samples were exposed to them. All the softwood samples were soluble in hot concentrated H_2SO_4 (Table **2**). Destructive distillation of the softwood samples showed that the wood charcoal from *Tetrapleura tetraptera* had the maximum value of 5.2g. *Allanblackia floribunda, Afzelia bella* and *Afrormosia laxiflora* each with 4.5g have appreciable quantities of wood charcoal. The least values of charcoal 1.5g and 1.75g were obtained in *Anogeissus leiocarpus* and *Sacoglottis gabonensis.* Others fell within the range of 2g and 4g as shown in Table **3**. Pyroligneous acid volume produced in *Afzelia bipindensis, Cassipourea barteri* and *Khaya ivorensis* each was 3.00cm^3 while *Combretodendron macrocarpum* (1.5cm^3) had the minimum pyroligneous acid. There was minimal production of wood tar in all the samples. The tar volumes were between 0.1 and 0.25cm^3 in the entire sample (Table **3**). *Monodara tenuifolia, Anogeissus leiocarpus, Amphimas pterocarpoides, Afzelia bipindensis* and *Cassipourea barteri* each had 0.25cm^3 as the highest value. The volumes of wood gas emitted were high. The maximum emissions of 998 and 980cm^3 from *Afzelia bipindensis* and *Sacoglottis gabonensis* shows that even the least emission of 512cm^3 from *Sterculia oblonga* still yielded an appreciable quantity of wood gas. Ash content of samples ranged between 2% and 5.5% with *Cassipourea barteri* (5.5%) generating the maximum

Table 2: Result of the Solubility Property of Nigerian Softwood Samples

S/N	Wood Sample (Botanic names)	Hot and cold water	1.0M Dilute HCl	Concen-trated HCl	Concen-trated HCl + heat	1.0M Dilute H_2SO_4	Concen-trated H_2SO_4	Concentrat ed H_2SO_4 + heat	1% NaOH	Ethanol	Diethyl ether
1.	*Monodara tenuifolia*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
2.	*Moringa oleifera*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
3.	*Protea ellilottii*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
4.	*Barteria nigritian*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
5.	*Anogeissus leiocarpus*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
6.	*Allanblackia floribunda*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
7.	*Glyphea brevis*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
8.	*Sterculia oblonga*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
9.	*Uapaca guineensis*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
10.	*Amphimas pterocarpoides*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
11.	*Albizia adianthifolia*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
12.	*Dichapetalum barteri*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
13.	*Afzelia bipindensis*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
14.	*Afzelia bella*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
15.	*Dichrostacys cinerea*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
16.	*Pentaclethra macrophylla*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
17.	*Tetrapleura tetraptera*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
18.	*Afrormosia laxiflora*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
19.	*Sacoglottis gabonensis*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
20.	*Cassipourea barteri*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
21.	*Combretodendro n macrocarpum*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
22.	*Cordial millenii*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
23.	*Khaya ivorensis*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble
24.	*Kaempferia galangal*	Insoluble	Insoluble	Insoluble	Slightly Soluble	Slightly Soluble	Slightly Soluble	Soluble	Insoluble	Insoluble	Insoluble

ash content. *Monodara tenuifolia, Anogeissus leiocarpus, Allanblackia floribunda, Albizia adanthifolia, Dichapetalum barteri* and *Pentaclethra macrophylla* each with 2% ash content had the least value among the softwood samples. This values are at variance with ash yield obtained from softwoods grown in the temperate zones whose values fall within the range 0.1-1.0% [9, 10].

4. DISCUSSIONS

Solubility of the softwoods were shown to take place in hot concentrated H_2SO_4 (Table **2**) this was supported by Horvath [11] that when the temperature of heated soft wood rises to the supercritical condition, then all the extractives together with cellulose components become soluble. Slight solubility was recorded in dilute H_2SO_4, concentrated H_2SO_4 and concentrated but

Table 3: Result of Thermochemical Properties of Some Nigerian Softwoods

S/N	Wood Sample (Botanical Name)	Wood Charcoal (g)	Pyroligneous Acid (cm^3)	Wood Tar (cm^3)	Wood Gas (cm^3)	Ash Content (%)
1.	*Monodara tenuifolia*	3.5	2.25	0.25	760	2.0
2.	*Moringa oleifera*	3.5	2.0	0.1	720	2.5
3.	*Protea ellilottii*	4.0	1.75	0.1	810	4.0
4.	*Barteria nigritian*	2.5	2.0	0.1	695	2.5
5.	*Anogeissus leiocarpus*	1.5	2.25	0.25	625	2.0
6.	*Allanblackia floribunda*	4.5	2.5	0.1	815	2.0
7.	*Glyphea brevis*	3.0	2.25	0.2	650	2.5
8.	*Sterculia oblonga*	3.0	2.0	0.2	512	2.5
9.	*Uapaca guineensis*	2.5	3.0	0.2	809	3.0
10.	*Amphimas pterocarpoides*	3.0	2.5	0.25	782	2.5
11.	*Albizia adianthifolia*	3.0	2.25	0.2	930	2.0
12.	*Dichapetalum barteri*	3.5	2.0	0.1	727	2.0
13.	*Afzelia bipindensis*	2.5	3.0	0.25	998	3.5
14.	*Afzelia bella*	4.5	2.25	0.1	630	2.5
15.	*Dichrostacys cinerea*	3.5	2.0	0.1	643	2.5
16.	*Pentaclethra macrophylla*	3.0	2.25	0.2	651	2.0
17.	*Tetrapleura tetraptera*	5.2	1.9	0.1	590	3.5
18.	*Afrormosia laxiflora*	4.5	2.25	0.1	832	4.0
19.	*Sacoglottis gabonensis*	1.75	2.25	0.2	980	5.0
20.	*Cassipourea barteri*	2.0	3.0	0.25	610	5.5
21.	*Combretodendron macrocarpum*	4.0	1.5	0.1	726	5.0
22.	*Cordial millenii*	2.0	2.25	0.2	902	2.5
23.	*Khaya ivorensis*	4.0	3.0	0.1	811	2.5
24.	*Kaempferia galangal*	3.5	2.0	0.1	780	3.5

heated HCl. This observation confirmed the statement by Horvath [11] that "most of the nonstructural wood constituents can be removed by extraction with suitable solvents, such as water, acetone, benzene, ether, ethanol, dichloromethane, methanol, hexane, toluene, tetrahydrofuran, and petrol ether. These solvents can be divided into hydrophilic (acetone, ethanol) and lipophilic (benzene, ether, petrol ether) compounds". Therefore, some of those solvents could actually be used for extracting nonstructural wood constituents. From the results, hot concentrated H_2SO_4 is a suitable solvent for dissolving the softwoods investigated. The samples remained insoluble in hot and cold water, dilute HCl, concentrated HCl, NaOH, ethanol and diethyl ether [6]. The implication of being non dissoluble in most of the solvents investigated shows the resilience of these softwoods. Thus most of them are good for use in boat making, bridge construction, doors and furniture making, house construction and other timber uses. Therefore, they will be able to withstand daily chemical reactions, enzyme and microbial activities as well as other elements in the environment.

The destructive distillation of each softwood sample in this research showed that the wood charcoal from *Tetrapleura tetraptera*, *Allanblackia floribunda, Afzelia bella* and *Afrormosia laxiflora* each have appreciable quantities of wood charcoal. The general range of charcoal in all the softwoods examined was 1.5–5.2g, thus, softwoods are great sources of charcoal. The implication of this is that they have great potential for different domestic and industrial purposes such as; cooking, water treatment (activated charcoal), removal of pesticides, dermal care, whitening of teeth (powdered activated charcoal), mulching, for moisture absorption in bathrooms and household appliances, prevent rusts in tools, treatment of alcohol poisoning and hangover, anti venom removal of toxin in animals, buffer against drug overdose and prevention of root rots in plants.

Pyroligneous acid volume produced in *Afzelia bipindensis, Cassipourea barteri* and *Khaya ivorensis* were appreciable (Table **3**). According to Dobele *et al.* [12] "technologies for fast pyrolysis of wood are progressing rapidly, which enables the conversion of solid wood biomass into a liquid product – bio-oil, which can be used as a fuel or as a raw material for producing valuable chemicals". Jahirul *et al*. [13] stated that "fast pyrolysis produces 60%–75% of oily products (oil and other liquids)". Jahirul *et al*. [13] summarizes uses of pyrolysis bio-oil as: fuels (Hydrogen and fuel *via* syngas), chemicals (resins, fertilizer, flavours, adhesive, acetic acid, and industrial feedstock), heat (for co-firing of boiler and furnace) and power (diesel engine and turbine). Other importance of pyroligneous acids include use in the production of essential oil (e.g. clover oil) biopesticides (canola oil) [1], botanical oils for insect control [14, 15].

Wood tar from this research showed that *Monodara tenuifolia, Anogeissus leiocarpus, Amphimas pterocarpoides, Afzelia bipindensis* and *Cassipourea barteri* had the highest quantity of the lot examined. Some known uses of wood tars include coating for wooden boats as waterproofing agent, adhesives applications, use in soap, cosmetics, dye and medical applications. Wood tars have protective effect on the wood, especially from insects.

The highest component in the destructive distillation of wood apart from charcoal is wood ash. Many uses are made of wood ash in domestic, agricultural and industrial application. Wood ash can be used on some agricultural soils to enhance crop production by raising soil pH (liming) as well as for landfill purposes [16]. Jayalakshini *et al.* [17] explained that "wood ash improves soil texture, bulk density, permeability, water holding capacity/porosity/aeration, fertility status, resistance to pest attack, and reduces crust formation". Ashes from woods are used traditionally in the production of soap and as well as catalysts in production of fermented food substances and cooking of foods.

The volumes of wood gases from these samples are appreciable as depicted from the result. The importance of gases generated in the destructive distillation of woods is generally needed for energy generation. Oluoti *et al*. [18] is in agreement to the fact that energy is paramount in biomass consumption when they stated that "besides using wood as fuel for cooking, gasification of these resources offers a better option for producing power, heat and biofuels for a wider variety of applications and that wood gas produces raw synthetic gas ($CO + H_2$), hydrogen and some other minor byproducts. The syngas is cleaned and eventually used to generate electricity", it can also be converted to methanol, natural gas and biodiesel for use in gas generators, cars and local heating grid. Wood gas use has been quite old. It was popular during World War II. Breag, and Chittenden [19] explained that "by 1945 the gas was being used to power trucks, buses and agricultural as well as industrial machines. It is estimated that there were close to 9,000,000 vehicles running on producer gas all over the world, however the discovery of fossil oil caused decline in exploitation of biomass based gas".

CONCLUSION

Careful harnessing of the components of destructive distillation of woods generally, *ipso facto* Nigerian softwoods can be of agricultural, industrial and domestic uses. This however, needs the appropriate technology to be effective. This research established the thermochemical components present in Nigerian softwoods, their quantification as well as solubility properties of the various softwood examined. It also looked into the possible application of these components.

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