# EVALUATION OF PHYSICOCHEMICAL, POLYMERIC AND METAL CONTENTS OF SELECTED TROPICAL TIMBERS IN NIGERIA

### VERONICA OBIAGELI EZIGBO

### 2009547003P

### DEPARTMENT OF PURE AND INDUSTRIAL CHEMISTRY,

### FACULTY OF PHYSICAL SCIENCES

### NNAMDI AZIKIWE UNIVERSITY, AWKA

**MARCH, 2019** 

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# VERONICA OBIAGELI EZIGBO 2009547003P

# A THESIS SUBMITTED TO THE DEPARTMENT OF PURE AND INDUSTRIAL CHEMISTRY IN THE FACULTY PHYSICAL SCIENCES NNAMDI AZIKIWE UNIVERSITY AWKA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

**MARCH, 2019** 

### CERTIFICATION

I EZIGBO, VERONICA OBIAGELI hereby certify that I am responsible for the work in this project/ thesis/ dissertation and that this is an original work which has not been submitted to this university or any other institution for the award of a degree or diploma.

Signature of Candidate

Date

4

### APPROVAL PAGE

This Thesis written by **Veronica Obiageli Ezigbo** has been examined and approved for the award of Degree of Doctor of Philosophy from Nnamdi Azikiwe University Awka.

PROFESSOR A. N. EBOATU (Supervisor)

DR. I.O. OKERULU Date (Head of Department)

(External Examiner)

PROF. S.O. ANIGBOGU (Dean of Faculty)

PROF. I.H. ODUMEGWU (Dean School of Postgraduate Studies) Date

Date

Date

Date

### **DEDICATION**

This work is dedicated to the LORD GOD ALMIGHTY who made the entire programme a divine success.

#### ACKNOWLEDGEMENT

I thank God for seeing me through this research and for His grace, wisdom, knowledge, understanding and journey mercies in the course of this dissertation. My immeasurable and profound gratitude goes to my supervisor Professor A. N. Eboatu, for whom words cannot express my gratitude, you are a bundle of intelligence, an inspirator, a mentor and a father. May God continue to bless you and your family always. I appreciate in a special way, Prof. VIE Ajiwe for his fatherly assistance and contribution to this study. My thank also goes to the Head of Department, Pure and Industrial Chemistry, Dr. Okerulu for his advice. I thank also, Dr.U. C. Ekpunobi Coordinator of Postgraduate Studies of the Department of Pure and Industrial Chemistry, for her support and assistance. I thank also Dr H.N. Okoye who helped in proof reading this work. Mp0y profound gratitude goes to Mr. Obinna Okwuego, the lab technologist of Nwafor Orizu College of Education Nsugbe. I am also highly indebted to Mr. Okechukwu David, Manager Spring Board Research Laboratory, Udoka Estate Awka. I will not forget my elder brother and sister, Chief C. I. Ezigbo and Mrs. Okoye-Dekwo for all their kind advice. I am most grateful to my husband Mr. A. N. Offiah for his supportive role in seeing that this research work is accomplished. My thanks also goes to professor Izundu of the Botany Department of this university who identified and recognized the leaves of the selected timbers according to their scientific names. I thank in a special way my children Paul, Francis, Cornelius, Stella Maris, Christian, Juliet and Mary Cynthia for bearing with me all this time I was not there for them in accomplishing this study.

I also acknowledge Esther Ezigbo, Mrs. Felicia Aghaduno, Mr. & Mrs. Benjamin Igboeme, Chief Felix Ezigbo, Mrs. Theresa Nduanya and Chief Boniface Ezigbo, for their help. I am also grateful to Chibuike Agupugo and Mrs. Mkpogu Ngozi. Who typed and printed the work. My prayer towards all is that the good Lord will reward everyone according to His riches in glory through Jesus Christ, Amen.

#### ABSTRACT

The qualitative and quantitative phytochemical analyses of 50 timbers of Nigeria were carried out. The physicchemical properties such as polymeric test, phytochemical test, solubility test, proximate analyses, saponification value, iodine value, acid value and peroxide value and elemental analyses of the wood species were determined. Results showed that the range of experimental values of the chemicals as well as other physical parameters were: moisture content (9.2 - 34.4 %), ash content (0.5 - 34.0 %), specific gravity (0.012 - 0.39), thermal conductivity (182.00 – 105665.00  $\mu$ ohm), charring temperature (60 – 94°C), porosity (0.06 – (0.068), crude fibre (33.78 - 40.74 %), fibre length (1.54 - 1.98 mm), cellulose (0.53 - 93.3 %), hemicelluloses (20.0 - 37.0 %), lignin (5.6 - 79.4 %), saponins (0.25 - 2.40 mg/100g), alkaloids (0.008 - 0.72 %), tannins (100 - 999 mg/g), carbohydrate (0.91 - 1.67 mg/g), acid value  $(8.40 - 15.60 \text{ g}/1000 \text{ cm}^3)$ , protein (7.30 - 12.10), resins (0.57 - 2.9), and pH (4.10 - 10.10)6.72), solubility in cold water at  $20^{\circ}$ C (0.80 – 10.60 mg/g), solubility in hot water at  $100^{\circ}$ C (1.99 - 14.25 mg/g), solubility in ether (0.12 - 2.25 mg/g), solubility in 1 % NaOH (10.03 -38.12 mg/g), Iodine value 16.89mg/g. 22.95 mg/g) saponification values (101.95 mg/g -197.25 mg/g) flavonoid (0.24 % - 0.96 %), oil content (0.29 % - 1.82 %), cardiac glycoside (0.37 mg/100g - 0.97 mg/100g, fibre saturation point (FSP) (21.0 - 28.50 fatty acid (3.07 -7.13 %), peroxide value (7.34 mg/g - 10.10 mg/g), calcium (5.594 ppm - 109 ppm), copper (0.004 ppm - 1.075 ppm), potassium (3.577 ppm - 257.296 ppm) cobalt (0.006 ppm - 0.788 ppm), sodium (4798 ppm - 96.366 ppm), magnesium (5.266 ppm - 72.482 ppm), cadmium (0.001 ppm - 0.329 ppm), lead (0.55 ppm - 3.037 ppm), manganese (0.145 ppm - 8.215 ppm), Iron (0.358 ppm – 35.700 ppm). The ANOVA results showed that the concentration of the phytochemical analyses, proximate analyses, polymeric analysis and elemental analysis were significant. The summary of the multiple comparisons showed that protein is most significant among the phytochemical, crude fibre is the most significant among the proximate analysis, lignin is the most significant among the polymeric contents and potassium the most significant among the elemental contents. These results indicated that the fifty tropical wood/timbers had chemical constituents which might be useful to pharmaceutical industries and other industries. From the results obtained, baseline of physicochemicals and heavy metals in tropical timbers have been estimated.

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### CHAPTER ONE INTRODUCTION

#### 1.1 Background of Study

A native forest typically consists of many botanical species. A forest like the Boreal forest in Germany and rain forest in Nigeria comprise both soft and hard wood trees (Hoadley and Bruce, 2000). When processed for lumber, this produces wood for pulp and paper or timber for construction and furniture purposes or energy through burning and waste that can be used as an energy source or for extraction of valuable compounds such as essential oils or bioactive chemicals. The forestor plant biomas in general consists of what is generally referred to as lignocelluloses (Greeg and Saddler, 1995). Lignocellulose materials consists of 3 main chemical components namely cellulose a carbohydrate biopolymer made up of repeating residues of glucose and usually make up to 50% of the total weight of the plant biomass. The Hemicelluloces are ambiguously defined as group of carbohydrate biopolymers that exist in close association with cellulose in the plant cell wall and makes up between 20% and 30% of the weight depending on the plant species. Lignins are natural aromatic (85%) and phenolic (15%) polymers found in both the primary and secondary cell wall layers and is present to the extent of 20-30% and is species dependent(Greeg and Saddler, 1995). Wood is a hard fibrous tissue found in many plants. The use of wood is not only limited to building and construction, but also can be used in medicine and industries. The composition of wood is dependent on the geography and geochemistry of a place, hence plants in different places vary in chemical composition. Unfortunately, little information exists on the chemistry of tropical timbers compared to those of temperate climate. Hence, this study evaluated the chemical composition of tropical timbers in Nigeria.

### **1.1.1** Wood Chemistry and Formation

Timbers are known as trees grown to be used in building or in making other things; they can be referred to as extremely important versatile and beautiful raw materials. Wood comes from the trunk (main stem) of trees. A tree's stem serves two main purposes; to support the branches, leaves and flowers of the tree, holding these firmly, even against the buffeting of the wind and stoms. A tree's stem also serve as a transport system that transports water and nutrients from the roots to the leaves and to all the other areas of the living tree. Wood is an organic materials, a natural composite of cellulose fibre embedded in a matrix of lignin, which resists compression. It is a hard fibrous tissue found in many plants.

The cross-section of a tree trunk is made up of four principal layers. The outermost section is a ring of bark made up of two layers: an outer layer of dead corky material, the outer bark and an inner layer of live bark, the phloem. The outer layer is made up of epidermal cells that protect the stem from damage and from drying out. The phloem contains cell which form tall and thin tubes, like capillaries, which transport the sugars and other materials made in the leaves to all the other living cells in the tree. The next layer is the cambium which usually feeds slimy in a freshly cut stem. This thin layer is made of cells which produce phloem and xylem. The cambium is the only place in a stem where new growth takes place and its cells are constantly dividing to form, new wood and new bark. As a result of the continual division of cells, the cambium layer slowly moves outwards as the tree increases in growth. As the tree expands in growth, the outer bark periodically splits and is replaced by the new outer layer. The innermost layer of a stem is the xylem, living xylem can carry water and mineral, from the roots to the leaves. Dead xylem cells make up heartwood which is the tissue (group of cells) in the centre of the stem. It is composed mostly of hollow, elongated, spindle-shaped cells that are arranged parallel to each other along the trunk of a tree (Regis, 1999). In a living tree it transfers water and nutrient to the leaves and other growing tissues and has a support function, enabling woody plants to reach larger sizes or to stand up for themselves. Wood comes from tree. This is the most important fact to remember in understanding the nature of wood. Thus, knowing wood as it grows in nature is basic to working successfully with it (Bruce and Hoadley, 2000).

Wood, in the stick sence, is yielded by trees, which increases in diameter by the formation between existing wood and the inner bark, of new woody layers which envelop the entire stem, living branches and roots. Technically, this is known as secondary growth; it is the result of cell division in the vascular cambium, a lateral meristan and subsequent expansion of the new cells. The phloem contains cells which form tall and thin tubes which transport the sugars and other materials made in the leaves to all the other living cells in the trees. in girth, the outer bark periodically splits and it is replaced by the new outer layer (Regis, 1999). The inner most layer of a stem is the xylem living xylem cells carry water and minerals from the roots to the leaves. Dead xylem cells make up heartwood which is the tissue (group of cells) in the centre of the stem. As the trunk of a tree expands with secondary growth, new phloem forms on one side of the cambium tissue, and new xylem on the other. This secondary xylem is known as wood (Regis, 1999).

The chemistry, with respect to the hemicelluloses and lignins differs greatly between soft wood and hard wood tree species. Other polysaccharides, usually of mixed constitution, are also present but in lesser amounts. Trees also produce a host of other compound of varying chemical nature in minor and trace amounts, and some of high values find commercial applications. For example, wood bark which comprises about 13 to 21% of wood on a dry weight basis, contains a variety of chemicals, some being of economic importance when extracted, and especially as pharmaceuticals. Well known examples of bark extractives include taxol (for cancer chemotherapy) from Pacfic yew tree, quinine (antimalaria agent from the cinchona tree) and asprin (an analgesic from strychnus toxifera). Many natural products (phytochemicals) are used in pharmaceuticals. Aside from lignocelluloses, wood also consists of variety of low molecular weight organic compounds, such as terpenes, diterpenes and fatty acids, for example. Rosin is exuded by conifers as protection from insects. The extraction of these organic materials from wood provides tall oil, turpentine and rosin(Bruce and Hoadley,2000).

#### **1.1.2** Activity of the cambium

Some of the medullary ray cells, mostly in a line with the fascicular cambium become meristematic and form a strip of interfascicular cambium on either side and form a complete ring known as the cambium ring. As the vascular cylinder increases in girth, the cambium cylinder also grows in circumference by occasional division of cells in the radial plane. The neutar camoium is made up of two types of cells. They are those which are elongated with tapering ends, the so called fusiform initials and more or less isodiametric- the ray initials. The former give rise to all the elongated cells of secondary vascular tissue, namely the xylem tracheids, vessels, fibres and xylem parenchyma and the phloem sieve tubes, companion cells, fibres and phloem at right angle to the axis. These are the secondary medullary rays. Longitudina section of cambium is shown in Fig. 1.1 (Duta, 1981).



Figure 1.1 Longittudinal section of a cambiam (Duta 1981)

1.1.3 Secondary tissues: The cambium ring as a whole becomes actively meristematic and gives off new cells both externally and internally. Those cut off on the outer side are gradually modified into the elements of phloem; these constitute the secondary phloem. The secondary phloem consists of sieve-tubes, companion cells and phloem parenchyma and often also some patches of bast fibers. The new cells cut off by the cambium on its inner side are gradually modified various elements of xylem; into the these constitute the secondary xylem(Robarts, 1976).

The secondary xylem consists of scalariform and pitted vessels, tracheids; numerous wood fibres and some wood parenchyma. The cambium is always more active on the inner side than on the outer. Consequently xylem increases more rapidly in bulk than phloem and some form a compact mass. As a matter of fact, the secondary xylem forms the main bulk of the plant body after secondary growth. As the secondary cells increase, the pressure exerted by them and the cambium pushes the surrounding tissues outwards, and for the same reason, some of the primary tissue get crushed. The cambium forms some narrow band of parenchyma, radially elongated and passing through the secondary xylem and secondary phloem; these are the secondary medulary rays. 'These allow horizontal transport of water and solute inside the thicknened stem' (Roberts, 1976). Primary and Secondary tissues are shown in Fig. 1.2



Figure 1.2: Primary and Secondary tissues (Roberts.1976)

**1.1.4 Annual Rings:** The rate of secondary growth in stem varies with seasonal changes. During spring when more soil water is required, xylem vessels and tracheids are formed in large numbers. These conduct the required amount of soil water to the shoot. Later on, with the onset of autumn and winter, when very little water may be required, the number of xylem vessels and tracheids formed by the plant decreases. The cells formed during autumn and winter, i.e. during the period of slow growth, are small and thick walled so that the wood has a dark texture, while those formed during spring and summer are larger and have thinner walls, so that the wood has a light texture. Thus depending on seasonal changes and requirements of the plant itself, two types of xylem tissues are formed. One growth ring in a stem shows both types of xylem tissues formed during one whole year. Hence it is known as an annual ring and the age of the tree can be determined by counting the number of rings present. In tropical countries, growth rings are formed when favorable seasons (rainy seasons) alternate regularly with unfavorable seasons (dry seasons). Cut surface of a stem showing the annual rings is shown in Fig. 1.3 (Duta, 1981).



Figure 1.3: Cut surface of a stem showing annual rings (Dutta 1981).

#### 1.1.5 Heartwood and sapwood:

The woody part of a stem, the xylem cell that normally conducts soil water and other dissolved materials make up the sapwood. As the plant grows older, the older xylem cells (mainly vesels, tracheid and parenchyma) which occur towards the centre of the stem become thick-walled and lose their function of conduction. Often other substances such as resins, tannins, oils and gums are deposited in them. These xylem cells make up the heartwood. In some trees the heartwood rots while in others it is very strong and hard, and gives mechanical support (Duta, 1981).

#### 1.1.6 Origin and activity of cork-cambium:

The formation of new tissues by the cambium exerts a considerable pressure on the peripheral tissues of the stem. Sclerenchyma and collecnchyma become much flattened but it persists for a long time because of the elastic nature of the walls. To replace or to reinforce the peripheral

protective tissue, particularly the epidermis, a strip of secondary meristem called the corkcambium or phellogen arises in that region to give rise to new secondary tissues. The corkcambium commonly originates in the outer layer of collenchymas. In the formation of corkcambium the outer layer of collenchymabecomes meristematic; it divides and forms a thin strip of cork-cambium consisting of a few rows of narrow rectangular cells; these cells are living and active. The cork-cambinm takes on meristematic activity and begins to divide and give off new cells on both sides, forming the secondary cortex on the inner side and the cork on the outer side. The origin and activity of cork-cambium is shown in Fig. 1.4



Figure 1.4: Origin and Activity of cork-cambium (Dutta 1981).

### 1.1.7 Periderm and Bark Formation

The cells that are cut off on the inner side constitute the secondary cortex or phelloderm. Their cells generally contain chloroplasts and can photosynthesize. The new cells cut off by the cork-cambium on its outer side are roughly rectangular in shape and soon become suberized (impervious). They form the ork or phellem of the plant. All the new tissues formed at the peripheral region- the ork or phellem, the cork-cambium or phellogen and the secondary cortex or thelloderm are known as periderm.

**Bark:** All the dead cells, tissue lying outside the active cells-cambium constitute the bark of the plant. It includes the epidermis, lenticels and cork. The deeper the origin of the cork-

cambium the thicker is the bark. When the cork-cambium appears in form of a complete ring, the back formed goes away in form of a sheet and is known as ring bark, as in Betula. When it appears in strips, the bark formed goes away in form of scales and is known as scale-bark, as in guava. (Fig. 1.5)



Ring-bark



Scale-bark

Figure 1.5: Ring-bark and Scale-bark (Roberts 1976).

#### 1.1.8 Lenticels and anomalous secondary growth in dicotyledonous stem

A section through a lenticels shows that it consists of a loose mass of small thin-walled cells. At each lenticels the cork-cambium, instead of producing compact row of cork cells, forms spherical or irregular cells which are very loosely arranged. These cells form the lenticels and it commonly develops below a stoma and as its cells increase in number and size the epidermis gets ruptured. Through it the exchange of gases takes place between the atmosphere and the internal tissues.

The secondary growth of some diocotyledonous and gymnosperms deviate considerably from the form of growth just described. The deviating methods of secondary thickening are called atypical or anomalous" (Esan 2007). In some plants, part of the cambium originates in an abnormal position. For example, in Chenopodiceae, Amaranthaceae, Meais Permancease, Cycas and Gnetum, secondary growth begins from a fascular cambium in the normal position; another fascular cambium arises in the phloem or outside it and produces xylem towards the inside and phloem towards the outside. Still, another supernumerary cambium arises outside the first supernumerary layer and also forms xylem towards the inside and phloem towards the outside. In this sequence many cambia and many alternating layers of xylem and phloem may be formed. Anomalous growth in amaranthus stem is shown in Fig. 1.6.



Figure 1.6 Anomalous Growth in Amaranthus Stem (Dutta 1981)

#### 1.1.9 Intrinsic nature of wood trees

A tree is a large woody plant, with a main stem called a trunk, which does not usually branch until several feet from the ground. Trees are also perennials and are taller than shrubs. It is sometimes difficult to distinguish a shrub from a tree, for there are some plants like croton and Baphia nitida which usually remain as shrubs but may occasionally grow as tall as a tree. The size of tree also varies with the depth and type of soil in which it grows (Stone *et al.*, 1991). Wood is easily kindled and gives maximum intensity of heat very quickly. It burns with nonsmoky flame. Its calorific value varies from 300 to 4000 calories per kg for air-dried wood. As wood possesses low calorific values, it is rarely used in industry as a fuel; it is used to some extent as fuel more especially in domestic heating. It could not find general adoption as fuel on accounts of its price and low heat producing power (Uppal, 2003). The main drawback for using wood are its lower calorific value and high cost of transporting for large distances by rail. It has widely been used as a source of material for constructional purposes, a source of cellulose for the manufacture of paper rayon and other product. Wood has been a source of energy and chemicals for hundreds of years and continues to be important raw material for specific chemicals. The use of wood as a primary source of industrial chemicals decreased dramatically in the 1940s when oil became the preferred raw materials. (Annon, 1987).

A knot is a particular type of imperfection in a piece of wood, it will affect the technical properties of the wood, usually for the worse, but may be exploited for artistic effect. In a longitudinally sawn dank, a knot will appear as a roughly circular "solid" (usually darker) piece of wood around which the grain of the rest of the wood "flows" (Parts and rejoins).

Within a knot, the direction of the wood (grain direction) is up to 90 degrees different from the grain direction of the regular wood. Timber is said to be formed from stem or trunk of tree by the process of secondary growth. Secondary growth in thickness is the growth that is responsible for the increase in diameter of stems and roots. There are two types of secondary growths in dicotyledonous stems. These are normal and anormalous secondary growths. As the names imply, one is normal while the other shows some anomalies. This type of growth commences very soon after the primary cells or tissues have been fully formed.

Secondary growth in thickness is able to come about due to the meristamatic nature of cambium ring (fascular and interfascular cambium) and the cork cambinus or phellowderm. The cambium is made up of two types of cells: the fusciform initials and the ray initials. The former gives rise bundle (xylem and phloem) while the later gives rise to secondary medullary rays. Trees and shrubs experience two types of growth – primary growth and secondary growth. Apical or primary growth increases the length of stems and roots. Secondary growth in thickness increases the girth or diameter of plants. The cambium which is meristematic in function produces new cells of xylem and phloem. Later, corkcambium makes its appearance in the peripheral region and begins to form other secondary tissues (Phellem and phelioderm). This increase the thicknes due to the addition of secondary tissues cut off by the cambium and the cork-cambium in stellar and extra stella regions respectively is spoken of as secondary growth (Dutta, 1981) commences very soon after the primary tissue have been formed' (Vines and Revees, 1972). 'Monocotyledonous as well as dicotyledonous plants which develop into trees show a marked increase in girth (Ramahngan *et al.*, 1979).

#### **1.1.10 Wood Utilization**

Wood is a hard fibrous tissue found in many plants. It has been used for many centuries for both fuel and as a construction material for several types of living areas such as houses. Man has used wood for millennia, primarily as a fuel or as a construction material for making houses, tools, weapons, furniture, packaging, artworks and paper (Regis, 1999). Wood can be dated by carbon dating and in some species by dendrochronology, to make inferences about when it was created. It is made up of mainly cellulose, hemicelluloses, pectin and contains lignin as well as other materials such as resins, fats, and proteins. Its complex chemical makeup also makes it an ideal raw material for what could be future "lingo-chemical" industry that can replace the petrochemical industry in providing not only plastics and all kinds of chemical products but also food and textile products (Bashiru and Eboatu 1990). Wood is used to build bridges as well as water-mills and air-mills and micro hydrogenerators for electricity (Meyer, 1984). It has been a source of energy and chemicals for thousands of years and continues to be an important raw material for specific chemicals (Rowell 1982). Its use as a primary source of industrial chemicals decreased dramatically in the 1940's when oil became the preferred raw material. The importance of wood as raw materials supplying fiber, energy and chemicals is in the same magnitude to its use as a solid material. Lumber, plywood and reconstituted boards consume about one-half of the timber harvest. Usage for fibre, chemicals and fuels accounts for the remaining half (B.U.S, 1999). In 1990, over 55 millions metric tons of pulp fibre for paper making were derived from the forest (Rowell 1982). In January 2010, Italian scientists announced that wood could be enhanced to become a bone substitute, but it is likely to take at least five years until this technique will be applied for humans. Further developments include new lignin glue applications, recyclable, food packaging, rubber tyre replacement applications, antibasteria agents and high strength fabrics or composites (Anon, 1987). Most articles of furniture in homes and offices are made of wood materials. These wood items are subjected to attack, deterioration and damage by microorganisms such as bacteria and termites. Apart from these defects, on exposure for a long time in the environment or exposure to actions of acids, alkalis or oxidizing chemicals, wood deteriorates. Wood preservation such as tar oils derived from coal or wood distillate and made up of phenolic compound can be used for protecting wood from decay (Will, 1960).

The inherent factors that keeps wood in the forefront of raw materials are many and varied, but a chief attribute is of its availability in many species, sizes and shapes and conditions suit almost every demand. Wood has a high ratio of strength to weight and a remarkable record for durability and performance as a structural material. Dry wood has a good insulating properties against heat, sound and electricity, it tends to absorb and dissipate vibration under some conditions of use, and yet it is an incomparable material for such musical instrument as the violin. The grain patterns and colours of wood makes it an aesthetically pleasing material, and its appearance may be easily enhanced by stains, varnishes, lacquers, and other finishes. It is easily shaped with tools and fastened with adhesives, nails, screw, bolts and dowels. Damaged wood is easily repaired and wood structures are easily repaired and other corrosive agents, has high salvage value, has good shock resistance, can be treated with preservatives and five retardants, and can be combined with almost any other material for both functional and aesthetic uses (Regis, 1999).

#### 1.1.11 Economic Importance of Secondary Growth:

"The cork tissue of cork oak Quercus suber, a Mediterranean plant, is of considerable thickness and is the source of bottle cork'. (Dutta 1981). Still another person declared, 'the cork of Quercus suber (the cork oak), is a well known commercial product'. (Vines and Revees, 1978). 'Many of the fibres of commerce such as jute, hemp, flax, rhea (or ramie) etc are the bast fibres of secondary phloem. (Dutta 1981). 'From the plant's point of view the importance of secondary growth is that it greatly increases the thickness and strength of stem, thereby enabling it to grow to a much greater height than would otherwise be possible'. (Roberts, 1976). The wood and planks from these giant trees are used in producing varieties of things, for example Furniture-chair, table, cardboard agricultural implements such as hoes, shovels, heads of knives and diggers; Domestic utensil-wooden spoons and plates, mortars and pistles, musical instruments- wooden gong, wooden organ etc; educational materials- Black boards and easels, rulers, book rack. If there is nothing like secondary thickening, plants and shrubs can neither stand nor anchore firmly in the soil and the slightest wind will blow them down. Occurence of such an incident will bring about the extinction of some group of animals which depend on such plants for food. Biological equilibrium will be disturbed and ecosystem will be adversely affected since animals and plants, the two major living components of the environment, live an inter-dependent life. The oxygen generated by these plants (trees) is what sustains the metabolic processes in living things. One can say specifically, that if there is no plant, there will be no life. Again, there would be nothing like wood and timber. The fermentation of cellulose that results to the formation of alcohol fuel are:



### 1.1.12 HISTORY OF WOOD

Wood is probably man's oldest natural resource and its history as household articles is as old as time itself. Wood is beautiful, tough, improves with age and if carefully looked after, will last indefinitely. Archaeological excavations have uncovered wooden utensils and bowls dating back thousands of years which, when examined closely, resemble many of the basic spoons and tools that we use today. Because it is a relatively cheap natural material which is easily worked, wood is widely used to make quality products used in preparation of food (Rowell, 1982). In medieval folklore, certain trees were held to be sacred with supposedly protective powers. This superstition is still relevant today as we continue to "touch wood" to guard against bad luck. Superstition apart, the appeal of wood is that, it is a tactile material which invites you to touch as well as look at it. Wood is an extremely important, versatile and beautiful raw material. In Australia, about one cubic metre (m<sup>3</sup>) or one tonne of wood is used for every man, woman and child each year. Wood comes from living, growing trees and therefore is a renewable material. In many parts of Australia and other parts of the world, large areas of forest have been set aside and are managed primarily for the continued production of wood. Sustainable management of our forests, the primary source of wood we use, ensures a continual supply of wood to meet our present and future needs. Historically, different types of wood have served many purposes,

while other less available or less desirable species served only one or two needs. For example, because white oak is tough, strong and durable, it was highly prized for shipbuilding, bridges, cooperages, barn timbers, farm implements, railroads crossties, fence post and flooring. Woods such as black walnuts and cherry were used primarily for furniture and cabinets. Hickory was manufactured into tough, hard and resilient striking tool handles and black locust was prized for barn timbers. What the early builder or craftman learned by trial and error became the basis for deciding which species were appropriate for a given use in terms of their characteristics. It was commonly accepted that woods from trees grown in certain locations under certain conditions was stronger, more durable, more easily worked with tools or finer grained than wood from trees in other locations. Modern research on wood has substantiated that location and growth conditions do significantly affect wood properties (Young *et al.*, 1990).

In the United States, more than 100 kinds of woods are available to the prospective user; but it is very unlikely that all are available in any one locality. About 60 native woods are of major commercial importance. Another 30 wood types are commonly imported in form of logs, cants, lumber and veneer for industrial uses, the building trades and craft (Annon, 1987).

The gradual reduction in use of old-growth forests in the United States has reduced the supply of large clear logs for lumber and veneer. However, the importance of high-quality logs diminished as new concept of wood use have been introduced. Second-growth wood, the remaining old-growth forests, and imports continue to fill the needs for wood in the quality required. Wood is as valuable an engineering material as ever and in many cases, technological advances have made it even more useful (Regis, 1999). Also wood improves with age and if carefully looked after will last indefinitely. Wood is probably man's oldest natural resource and its history as a household article is as old as time itself.

### 1.1.13 MAN'S DEPENDENCE ON WOOD

The product of civilization from the most primitive stages to the highly developed technological era has been said to be linked with man's utilization of wood and wood product. For thousands of years, man has become so much attached to the use of wood to such an extent that even the progress of economical development in the highly developed countries such as USA, Britain, Nigeria etc. can come to a standstill if deprived access to the usage of wood and other forest products.With rapid development of modern science, other application of wood and forest abound. These range from pharmaceutical products, extraction of oils, resins, myriad of plant derived chemicals, prevention of erosion to mention but a few. More so, animals like

monkey, birds, chameleon etc. make their homes on these forest products. Hence, the dependence of man on wood and forest products cannot be over emphasized (Chukwu,1999). Some of the usefulness of trees/timbers and the origin of timber have been highlighted (Anon, 1987 and Regis 1999). It is known that a good number of the materials and equipment used in domestic, industrial, commercial, medical and research establishments are made of timber/wood.

#### 1.1.13.1 Domestic

It has been used for many centuries as fuel in domestic heating and as food packaging, recyclable, new lignin glue application, rubber tyre replacement applications, antibacterial agents and high strength fabricks or composites (Annon, 1987). It is known that a good number of the materials and equipment used in domestic homes are made of timber/wood. Some of these materials and equipment include tables, stools, chairs, wooden cupboards, mortars and pistils.

### **1.1.13.2** Industrial and Energy

Timber/wood has been used for many years in paper industry. It is an ideal raw material for what could be a future lingo-chemical industry that could replace the petrochemical industry in providing not only plastics and all kinds of chemical products but also food and textile products. Timber has widely been used as a source of cellulose for the manufacture of paper, rayon and other products. Some of these industries material and equipment include, cardboard sheets, papers, pencils, test tube holders, spoons, rulers, test tube racks, reagent bottle racks, doors, windows, saw dust, door and window frames, textile materials used for clothing, mattresses, pillows, ceiling boards, tooth pick, to mention but a few.

Rubber is obtained from the latex of Hevea brasilensis, a big tree which is the main source of commercial rubber. Hevea brasiliensis is a native of the Amazon Region of Brazil but it is nowadays grown in plantations in different parts of the world, e.g. Nigeria, Srilanka and Malaysia. Natural rubber is a type of polyisoprene known as a polyterpene,  $(C_5H_5)n$ , and exists in two isomeric forms (Structure 1). Timber and firewood (fuel), together with many useful forest products, constitute the forest wealth of a country.
The two isomeric forms of natural rubber.



Structure ii:

The cis isomer has considerable elastic properties wheeas the trans isomer form, known as gutta-percha is non-elastic and when heated above 100°C, softens to a plastic-like material. Rubber is a polymer made of isoprene units and containing cis double bonds. An isoprene polymer in which the double bonds are trans is obtained from trees of the genus Dichopsis. The polymeric material, which has properties quite different from those of rubber, is called gutta percha (Ege, 1989). Gutta-percha is used for the covering of underwater cables and golf balls. The rubber is used for the making of tyres and tubes of wheels of various types of vehicles, aircraft, sols, rubber shoes, rubber sheets, rubber tubings, rubber belts, insulation of electric wires and various other goods of commercial importance. Paper: Cellulose is the basic constituent of paper. It is obtained from the wood of various trees. Wood is used in the manufacture of these materials: printing paper, writing paper, newsprint, wrapping paper,

cardboard and poster paper. Alcohol, known as ethanol is extracted from palm trees. It can also be synthesized from wood (saw dust) by fermentation process; saw dust is a cellulosic material. It can be hydrolyzed to glucose by the addition of dil. H<sub>2</sub>SO<sub>4</sub> and steam at about a pressure of 6 atmospheres. Ethanol is a good solvent used to dissolve soaps, perfumes, flavouring extracts, dyes, varnishes, drugs etc. it is also used in the manufacturing of alcoholic drinks such as wines, beers and spirits (eg gin, whisky, rum, brandy etc). Ply wood is made of a number of veneers (laminations) which are glued together with the grain of each at right angles to its neighbor and then placed in a press. A variety of timbers is used in making plywood. Trees are of paramount importance worldwide in that they are both biologically and economically important to man Biologically, plants (trees) and animals (including man) live an interdependent life. This can be seen in the area of (I) Taking in of carbon (IV) oxide and giving out oxygen, (II) Synthesis of food, (III) Animals die and decay to form plant food. Trees are essential for the existence of all kinds of life. Their importance lies in the fact that they are the only living organism that can introduce natural pure and cool oxygen into the atmosphere or the environment. They absorb carbon (IV) oxide from the atmosphere and release an almost equal volume of pure oxygen to it.

$$6CO_2 + 6H_2O + Energy \longrightarrow C_6H_{12}O_6 + 6O_2$$
 1.5

Trees manufacture food by the process of photosynthesis. Photosynthesis is the process by which green plants make their food (starch) from simple inorganic substances (CO<sub>2</sub>, H<sub>2</sub>O, mineral salts) in the presence of sunlight. Oxygen is given out as a by-product. The existence of man or animals would be impossible and unthinkable without trees. The primary necessities of man are threefold; food, clothing and shelter. All these are extensively supplied by trees or plants. Trees are indispensable sources of both coarse and fine fibres used in the manufacture of cloths or garments. Camphor: Camphor is obtained from the wood and leaf of Cinnamomum camphora, a tall tree of China, Japan and Taiwan origin. It has a characteristic strong but agreeable odour and is widely used in very small quantities in perfumery and medicines. Camphor is very slightly soluble in water but readily soluble in alcohol and ether. It volatilizes very slowly. Its odour scare insects away and it is used in the preservation of cloths. Synthetic camphor is also in wide use. It is made from pinene, a derivative of turpentine (Finar, 1977). Cinnamon is the dried brown bark peeled off from Cinnamomum zeylanicum, a small tree of Ceylon. It is grown in Kanara, Mysore, Travancore and Assam. Cinnamon bark contains a volatile oil, tannin, sugar and gum. It is aromatic and tastes sweet. It is extensively used for flavouring foods and vegetables. Cinnamon oil is extracted from the bark and leaf of cinnanomum tree. It is used in combination with certain drugs as an intestinal antiseptic (Dutta, 1982). Bay leaf: is the dried leaf of Cinnamomum tamala, a tree growing in many parts of India. The leaves are widely used as a spice for flavouring various kinds of curries, fruit and vegetable preserves, and often tea infusion. Myristica fragrans is a big evergreen tree grown abundantly in India, in the Western Ghats Range.

Cinchona is the famous quinine yielding plant. It is a low tree (6-15metres high). The bark of the plant was in use in South America till the late 19<sup>th</sup> century. The plant yielding this bark was discovered in Peru as late as 1739 by La Condamine, and in 1742 Linnaeus named it Cinchona after the countess of Chinchon, wife of a Spanish viceroy of Peru, who was cured of an attack of malaria fever by the use of its bark in 1638 (Dutta 1981). The aqueous extract from "Dogonyaro" or neem is used to cure malaria fever in Nigeria. The aqueous extracts from Baphia nitida and Napoliana vogelii are also used to cure diarrheoa. The roots of plants that anchore in the soil help in the checking of erosion. Lastly but not the least, timber as a useful raw material obtained from trees should be emphasized on. Timber is the wood (heart wood) used for various building purposes: houses, boats, bridges, ship, etc; for making furniture, packing boxes, matchsticks and boxes; for making plywood, tea chests, flush doors, partitions, walls, ceiling, shelves, cabinets, prefabricated houses, commercial boards, etc, and for railway sleepers. In addition, wood chips and shavings are used for making compressed wood which is in demand for paneled door, table tops, room partitions, hard blocks etc. Timber and firewood (fuel), together with many useful forest products, constitute the forest wealth of a country. The present rate of deforestation in Nigeria is a warning to the future need of wood in the country. Systematic afforestation is the only means of maintaining a balance between loss and gain. The quality of timber depends on its hardness, strength, weight, presence of natural preservatives like tannin, resin, etc, durability against heat, moisture and insect attack, workability, grains, colour, porosity and capacity to take polish and varnish.

### 1.1.13.3 Pharmaceutical

Timbers or wood produce a host of compounds of varying chemical nature in minor or trace amounts, and some of high values find commercial applications. For example, wood bark which comprises about 13 to 21 % of wood on a dry weight basis contains a variety of chemicals, some being of economic importance when extracted, and especially as pharmaceuticals. Well known examples of bark extractives include taxol (for cancer chemotherapy) from pacific yew tree, glunine (antimalaria agent from the cinchona tree) and sprin (an analgesic from strychnus toxifera). Many natural products (phytochemicals) are used in pharmaceuticals.

# 1.1.13.4 Construction

Timber/ wood has been used for many centuries as a construction material for making houses, tools, weapons, furniture, packaging, artworks doors, windous, shelf, door and window frames wooded beds, some parts of ships lorries, garden implements e.g. rakes, shovels, had fork, hoes, matchets, cutlasses wooden harger and others are all made of wood /timber.

# 1.1.13.5 Cultural and Religious

Wood/timber can be dated by carbon dating and in some species by dendrochronology, to make inferences about when it was created.

# **1.2 Problem Statement**

A cursory look at the literature showed that there is only few published work on the chemistry of tropical timbers but a voluminous one on temperate timbers. (Eboatu and Altine, 1991). The chemistry of these timbers will evaluate some claims by some health and furniture officers about the medicinal and woodwork of the timbers.

# **1.3** Aims and Objectives:

The aim of the study was to evaluate the physicochemical, polymeric and metal contents of fifty tropical timbers in Nigeria.

The objectives were to:

- Determine the level of polymeric components of fifty tropical timbers in Nigeria.
- Identify and determine the level of some phytochemicals constituents of the timbers.
- Determine the proximate properties of the timbers.
- Determine the metal contents of the tropical timbers .

# 1.4 Significance of the Study

(a) This work will supply valuable information about the physico-chemical and metal contents of fifty tropical timbers.

(b) The knowledge one acquires in this work will help one to make a wise choice of timbers in anything he/she wants to use them for.

(c) This research will confirm the chemistry of tropical timbers instead of temperate timbers.

(d) Current levels of Ca, Cu, K, Co, Na, Mg, Cd, Pb, Mn, and Fe in fifty Nigerian timbers have been determined.

(e) This research has shown a better source of the various timber species which will save time and effort in trying to ascertain a sourcing material when the need arises.

(f) The result of this study will form a future reference (data base) for Nigeria timbers.

(g) A wise choice of timbers for various purposes can be made from the data generated in this work.

(h) Developing wood cells represents one of the most important sinks for excellent atmospheric carbon (IV) oxide, thereby reducing one of the major contributors to global warming.

# 1.5 Scope of Study

The research covered the timbers obtained from eleven states in Nigeria.

The study examined the physico-chemical, polymeric and metal content of fifty samples of timbers.

The chemical characteristics of the selcted timbers were studied by determining the following components:

- 1. Polymeric components which, include cellulose, hemicelluloses and lignin.
- 2. Phytochemical compositions which include alkaloids, flavonoids, saponnins, resins, protein, oil, cardiac glycosides, tannins and carbohydrates.
- 3. Chemical composition of the oil extracted which include: Saponification value, iodine value, acid value and peroxide value.
- 4. The physical characteristic of the selected timbers will studied by determining the following: Ash content, moisture content, pH, specific gravity, porosity index, fibre saturation point, crude fibre, fibre length, thermal conductivity.

#### **CHAPTER TWO**

#### LITERATURE REVIEW

#### 2.1 Chemical Composition of Wood

Plant products can be used either as insecticides for killing larvae or adult mosquitoes or as repellents for protection against mosquito bites, depending on the type of activity they possess. Phytochemical analytical studies have confirmed that traditionally used medical plants produce a variety of compounds of known therapentic properties (Harbone and Baxter, 1995). The search for phytochemicals of plant origin having repollency activities against the malaria causing vectors and other diseases like malaria, dengue, ferer, Japanese Encephalitis have been mainly stimulated by the fact that some of the major repellents like DEET and DDT have considerable drawback in term of resistance and toxicity. Phytochemicals obtained from plants with proven mosquito control potential can therefore be used as alternative to synthetic insecticides or along with other insecticide under the integrated vector control.

A cursory look at the literature shows that there is few published work on tropical timbers but a voluminous one on temperate timbers and non-woody tropical plants. Among these published work are those of Eboatu and Altine, (1994) who studied the thermal characteristics of some tropical wood.

Additional work by Eboatu *et al.*, (1999) determined the fibre characteristics of some fire tolerant of the Sudan Saranna of Nigeria.

Rowell *et al.*, (1984) studied the chemical modification of wood. He reported that the properties are for the most part, a result of the chemistry of its cell. If the chemistry of the wood cell wall polymers is changed, the polymer properties change as does the performance of the modified wood.

Tijjani *et al.*, (2012) studied the phytochemical, elemental and anti inflammatory evaluation of stem bark methanolic extracts of *Piliostigms thoningis*. They reported that the anti-inflammatory properties of *Piliostigms thonningi* stem bark methanolic extract. The anti-inflammatory activities of the exract may be due to its content of flavonoid, and tannins. Flavonoids apart from acting as anti-oxidants are known to inactivate enzymes and these may be responsible for anti-inflamatory activities.

Eboatu and Momoh *et al.*, (1990) have worked on the flammability of tropical wood and investigated on the burning parameters.

Ekebafe (2009) has worked on improving the flammability of polymeric materials of wood.

Ak et al., (1994) also reported the inhibitory properties of wood against microorganisms.

Udeozo *et al.*, (2011) worked on some fire characteristics of fifty-two, Nigerian timbers. They reported that there appeared to be a direct relationship between flame duration and their oven dry densities. Density though an important factor in determining fire characteristics of timbers, should not be exceptionally used as a parameter without considering the cellular structure, molecular composition and timber extractives. Preliminary phytochemical screening and antibacterial activity on stem bark extracts of cross *Ptelyx febrifuga* was carried out (Tor-Anyiin and Shimbe, 2012). Phytochemical analysis of *C. febrifuga* revealed the presence of flavonoids, saponins, steroids, tannins and cardiac glycosides. These phytocompounds perhaps are responsible for the significant role in the in vitro antibacterial activity of this plant (Adegboye *et al.*, 2008).

Other research activities on African timbers include the joint work of Ajayi, *et al.* (2008) who studied the effect of wood density on bending strength and dimensional movement of flakeboards from *Gmelina arborea* and *Leuco cephela*.

#### 2.1.1.1 Wood Flavonoids

Flavonoids are colourful compounds that are present in most plants. They are what make red beets red and blueberries blue. They are also responsible for giving flowers their broad range of colors. Trees contain flavonoids with some species containing more than others. In some types of wood, these flavonoids are apparent right from the start. The wood may be yellow, red or other colours depending on the species. But in several species of wood, these coloured flavonoids may not become visible unless the wood is exposed to some type of acid. One exterior walls bright sunlight usually fades the colour within a couple of weeks. Consequently, for interior situations, the colour can be essentially permanent and since it is not just on the surface it may be impossible to remove by sanding, bleach or cleaning agent.

It is impossible to predict if wood is susceptible to flavonoid staining by just looking. Flavonoids are secondary metabolites, also referred to as bioflavonoids, water soluble polyhenolic molecules containing 15 carbon atoms. Hyonoids belong to the polyphenol family, and can be visualized as two benzene rings which are joined together with a short three carbon chain. One of carbons of the short chain is always connected to a carbon of one of the bezene rings, either directly or through an oxygen bridge, thereby forming a hard middle ring, which can be five or six-membered(Adegboye *et al*, 2008).

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Structure 2: flavenoid skeleton flavone

# 2.1.1.2 Classification of Flavonoids

According to the IUPAC nomenclature flavonoids can be classified into:

1. Flavonoids, derived from 2-phenylchromen-4-one (2-phenyl-1, 4-benzopyrone) structure (examples: que OH





Structure 4:

3. Neoflavonoids, derived from 4-phenylcoumarine (4-phenyl-1,2-benzopyrone) structure.



# Stucture 5:

Chemical structure of 4-phenylcoumarin (neoflavone skeleton).

# 2.1.1.3 Subgroups of Flavonoids

Flavonoids have been classified according to their chemical structure, and are usually subdivided into the 6 major subgroups. This includes: chalcone, flavones, flavonol, flavanone, anthocyanins and isoflavonoids.

1. Chalcones



Flavones (generally in herbaceous families, e.g. Labiatae, Umbelliferae, Compositae). HO HO OH

Structure 7:

2. Flavonol (generally in woody angiosperms)

Quercitol (example, Ruta graveolens, Fagopyrum esculentum, Sambucus nigra). Kaempferol (example sambucus nigra, Cassia senna and Equisetum arvense)



# 2.1.1.4 Functions of Flavonoids in Plants

Flavonoids are widely distributed in plants fulfilling many functions.

- 1. Flavonoids are the most important plant pigments for flower colouration producing yellow or red/blue pigmentation in petals designed to attract pollinator animals.
- 2. In higher plants, flavonoids are involved in UV filtration, symbiotic nitrogen fixation and floral pigmentation.
- 3. They may act as a chemical messenger or physiological regulator; it can also act as cell cycle inhibitor.
- 4. Flavonoids secreted by the root of their host plant help rhizobia in the infection stage of their symbiotic relationship with legumes like peas, beans, clover, and soy. Rhizobia living in soil are able to sense the flavonoids and this triggers the secretion of nod factors,

which in turn are recognized by the host plant and can lead to root hair deformation and several cellular responses such as ion fluxes and the formation of a root nodule.

5. Some flavonoids have inhibitory activity against organisms that cause plant disease e.g. *Fusarium oxysporum.* 

## 2.1.1.5 Effects of flavonoids on human health

- 1. The widespread distribution of flavonoids, their variety and their relatively low toxicity compared to other active plant compounds (for instance alkaloids) mean that many animals, including humans, ingest significant quantities in their diet. Preliminary research indicates that flavonoids may modify allergens, viruses, and carcinogens, and so may be biological "response modifiers". In vitro studies show that flavonoids also have anti-allergic, anti-inflammatory, anti-microbial (Cushnie and Lamb, 2005, Cushnie and Lamb, 2011), anti-cancer, and anti-diarrheal activities.
- The intake of foods containing certain flavonoids such as flavan-3-ols catechins) found in strawberries and green and black teas, kaempferol from brussel sprouts and apples, and quercetin from beans, reduces the risk of developing lung cancer.
- 3. Flavonoids have medicinal properties, especially their putative role in inhibiting cancer or cardiovascular diseases.

### 2.1.2 Wood Tannins

Tannins are found in leaf, bud, seed root and stem tissues. An example of the location of tannins in stem tissues is that they are often found in the growth areas of trees such as the secondary phlvem and xylem and the layer between the contex and epidesmis. Tannins may help regulate the growth of these tissue.

While in general, soft wood are much lower in tannins than hardwoods and are usually not recommended for use in an aquarium (Katie and Thorington, 2006) so using a hardwood with a very light color indicating a low tannin content an be an easy way to avoid tannins. Tannic acid is brown in colour, so in general white woods have a low tannin content woods with a lot of yellow, red or brown colouration to them tend to contain a lot of tannin (Katie and Thorington, 2006)

Tannins occur in many species of coniferous trees as well as a number of flowering plant families. These tannins can leach out of the plants. The water in the soil becomes rich with tannins and seeps into the ground water or drains into lakes and streams. These waters become brown in colour and look like tea. The word tannin comes from the old German word tanna meaning oak. It refers to the use of wood tannins derived from oak trees that were used to convert animal hides into leather.

Tannins are found commonly in the bark of trees, wood, leaves, buds, stems, fruits, seeds, roots and plant galls. In all of these plant structures, tannins help to protect the individual plant species. Tannins that become stored in the bark of frees protect the tree from being infected by bacteria or fungi. In this case, the tannins precipitate out the enzymes and other protein exudates from bacteria and fungi thus not allowing these organisms to infect the tree. Many bud scales on woody plants contain tannins to protect the inner leaf tissue from being consumed and in many seed pants the initial set of leaves from a germinating seed are also high in tannins.

Unripened fruits are high in tannin content. The high tannin content discourages fruit eating animals from consuming the fruit until the seeds are mature and read, for dispersal. As the fruit ripens the tannin content lessens.Beside fruits, tannins are also contained in coffee, tea, red wine and beer. The initial astringent taste when you sip a red wine actually comes from tannins in the wood of the oak barrels in which the wine was aged.Tannins are also responsible for many of the enchanting colours seen in flowers and the final beauty of autum leaves. Tannins also play a role in medicine and human health. The tannins in cranberries (vaccinium macrocarpon) have been medically proven to help prevent urinary tract infections in women by reducing the ability of the bacteria E. coli from adhering to cells lining the urinary tract.

Tannin is a secondary metabolites of plants, non-nitrogenous, phenolic in nature (Bisanda *et al;* 2003) an astringent, bitter plant polyphenolic compound that binds to and precipitates proteins and various other organic compounds including amino acids and alkaloids. Tannin, also called tannic acid, is any of a group of pale-yellow to light-brown amorphous substances in the form of powder, flakes, or a spongy mass, widely distributed in many species of plants, where they play a role in protection from predation, as pesticides, and in plant growth regulation (Katie and Thorington, 2006) and are distributed in species throughout the plant kingdom. They are manly found in both gymnosperms as well as angiosperms. Tannins are physically located in the vacuoles or surface wax of plants. These sites keep tannins active against plant predators, but also keep some from affecting plant metabolism while the plant tissue is alive; it is only cell breakdown and death that the tannins are active in metabolic effects. They are classified as ergastic substances, i.e. non-protoplasm materials and in cells. Tannins are also found in leaf, bud, seed, root, and stem tissues. According to Bate and Swain

(1962) tannins have molecular weight ranging from 500 to over 3,000 (garlic acid esters) and up to 20,000 hanthocyanidins) tannins are incompatible with alkalis, gelatin, heavy materials, iron, lime water, metallic salts, strong oxidizing agents and zinc sulphate, since they form complexes and precipitate in aqueous solution. In addition to their principal applications in leather manufacture and being tannins are used in the clarification of wine and beer, as a constituent to reduce viscosity of drilling mud for oil wells, and in boiler water to prevent sale formation. Because of its styptic and astringent properties, tannin has been reported to treat tonsillitis, pharyngitis, hemorrhoids, and skin eruptions; it has been administered internally to check diarrhea and intestinal bleeding and as an antidote for metallic, alkaloidal, and glycosidic poisons, with which it forms soluble precipitates. Soluble in water, tannins form dark blue or dark green solutions with iron salts, a property utilized in the manufacture of ink Tarcest *et al;* 1999

### 2.1.2.1 Classes of Tannins

There are three major classes of tannins, namely: hydrolysable tannins, nonhydrolyzable tannins (condensed tannins) and pseudo tannins.

### 2.1.2.2 Hydrolysable Tannins

Hydrolysable tannins (decomposable in water, with which they react to form other substances), yield various water-soluble products, such as gallic acid and protocatechuic acid and sugars. Gallotannin, or common tannic acid, is the best known of the hydrolysable tannins. The European chestnut tree (principally Castanea sativa) and the American chestnut oak (Quercus prinus) yield hydrolysable tannins important in leather manufacture.

### 2.1.2.3 Pseudo Tannins

Pseudo tannins are low molecular weight compounds associated with other compounds. They do not answer gold beater skin test, unlike hydrolysable and condensed tannins. (When gold beater skin or ox skin is dipped in HCl & treated with 1%  $FeSO_4$  solution, after washing with water it gives a blue / black colour). They are found in tea or coffee.





Structure 12a: Phloroglucinol

Structure 12b: Gallic acid

# 2.1.2.4 Uses of Tannins

- 1. Tannins are important ingredient in the process of tanning leather. Oak bark, mimosa, chestnut and quebracho tree have traditionally been the primary source of tannery tannin, though inorganic tanning agents are also in use today and account for 90% of the world's leather production (Marion and Roy, 2006).
- Tannin is a component in a type of industrial particleboard adhesive developed jointly by the Tanzania Industrial Research and Development Organization and Forintch Labs Canada (Bisanda *et al.*, 2003). Pinus radiate tannin has been investigated for the production of wood adhesives.
- 3. Condensed tannins, i.e. quebracho tannin, and Hydrolyzable tannins, i.e., chestnut tannin, appear to be able to substitute a high proportion of synthetic phenol in phenol-formaldehyde resins for wood particleboard.
- 4. The use of resins made of tannins has been investigated to remove mercury and methylmercury from solution (Torres *et al.*, 1999). Immobilized tannins have been tested to recover uranium from seawater.
- 5. In medicine, tannins can also be effective in protecting the kidneys. When incubated with red grape juice and red wines with a high content of condensed tannins, the poliovirus, herpes simplex virus, and various enteric viruses are inactivated.
- 6. Tannins have shown potential antiviral, antibacterial and antiparasitic effects.

7. Foods rich in tannins can be used in the treatment of HFE hereditary hemochromatosis, a hereditary disease characterized by excessive absorption of dietary iron, resulting in a pathological increase in total body iron stores.

## 2.1.3 Wood Alkaloids

Small quantities of nitrogen-containing compounds, like amino acids and protein can also be found as extractives in wood. Alkaloids are aromatic compounds with nitrogen as a heteroatom in some rings and are found in small quantity in the wood of tropical hardwoods, and in higher quantities in other plant organs. Alkaloids are compound of potent biological action in animals like humans, and some of the better known alkaloids such as quinine, berberine and strychrine have been detected in some wood extractives (Fengel and Wegener, 1989).

## 2. 1.3.1 Pyridine and Piperidine Alkaloids

Pyridine and piperidine alkaloids are a mono carbon hoop including one nitrogen atom and this group of alkaloids comprises numerous species of toxic plants that include venomous hemlock (*Conium, maculatum*), tobacco (*Nicotiana tobacum*) and lobelia. Incidentally, while tobacco is a member of the nightshade family, scientifically known as Solanaceae, poison hemlock is a member of the carrot family or Apiaceae. Coniine, a single ring compound produced in the plant from octanoic acid is a toxic alkaloid present in poison hemlock that is responsible for paralysis, asphyxia (suffocation) and ultimately death. Water hemlock or Cicuta douglasii, which is closely linked with poisonous hemlock, includes cicutoxin – a terpenoid resin. Incidentally, water hemlock is one of the most convulsive or most aggressively lethal indigenous plants found in North America. This plant is often mistaken for a parsnip root and in this case the chemicals present in the plant effect the central nervous system directly and most often leads to death (Fengel and Wagener, 1989)

#### 2. 1.3.2 Pyrrolidine Alkaloids

Alkaloids are basically derived from the amino acid called ornithine. This cluster of amino acid comprises the tropane alkaloids, atropine, hyoscine and hyoscyamine from the family of nightshade. For instance, the nightshade family includes henbane, belladonna, datura (thornapple), and bittersweet. Acting as a cluster hese alkaloids impede the activities of parasympathetic nerve (originates in the lower part of the spinal cord and brain stem, stimulates

digestive secretions, opposes physiological effects of the sympathetic nervous system, constricts the pupils; slows the heart, dilates blood vessels). Incidentally, the pyrrolidine alkaloids also comprise the 'truth medication' scopolamine (also known as hyoscine) and cocaine.

#### 2.1.3.3 Indole Alkaloids

Indole alkaloids comprise serotonin chemically known as 5-hydroxyltryptamine or 5-HT and others of their kind. These comprise the anesthetizing alkaloids of the passion flower, ophthalmic alkaloids associated with the physostigmine derived from the Calabar bean as well as the uterine tonics such as ergotamine. This variety of alkaloids also comprises the Indian snakeroot or the Rauwolfia serpentaria that consist of reserpine. Among the numerous central nervous stimulants such as strychnine, psilocybin and johimbine, indole alkaloids comprise indole carbon-nitrogen loop. Indole carbon-nitrogen ring is also present in the fungal alkaloids ergine and psilocybin, the neurotransmitter serotonin as well as the mind jerking medication LSD. Researches have shown that these alkaloids may often impede, obstruct or even contend with the action of serotonin in the brain. Interstingly, one of the strange aspects of alkaloids that occur naturally in the fungi includes ergot, known as Claviceps purpurea, which is basically a rust fungus that contaminates grains. Incidentally, the alkaloid of ergot is also known as ergine or D-lysergic acid amide. It is popularly known as the natural LSD. Synthetic LSD or D-lysergic acid diethylamide is more powerful than the natural LSD. Two genuses of Mexican morning glory vines also contain natural LSD and these vines are consumed by the native Indians there during significant therapeutic as well as religious ceremonies. Bufotenine, another enthralling indole alkaloid is widely present in yopo or parica or 'Anadenanthera peregrina' seeds. The yopo is a South America leguminous tree found in the Orinoco river basin and is different from the leguminous species anadenanthera. Native Indians in the Orinoco river basin collect the yopo seeds, make their powder and use them as a hallucinogenic snuff. Bufotenine is also of the 5-hudroxyldimethyltryptamine or 5-HT variety and is generally obtained from the indole alkaloid called tryptamine. Tryptamine is derived from the indispensable amino acid called tryptophan. Tryptophan comprises one of the eight necessary nutritional amino acids for the human beings and is also extensively found in the animal kingdom. Significantly, tryptophan cannot be synthesized by the humans (Obadoni and Ochuko, 2001).

Reserpine, an indole alkaloid, is obtained from the roots of a shrub known as snakeroot or 'Rauvolfia serpentina' commonly found in India. Reserpine belongs to the dogbane family of 'apocynacear and the species also often spelled as 'rauwolfia' is alike with serotonin and has been often used to cease schizophrenin-like indications from LSD as well as the brain reducing activities in the case of patients suffering from the schizophrenic malady. A highly venomous alkaloid known as strychnine is another indole alkaloid that is obtained from the seeds of strychnos nux-vomica. Strychnos nux-vomica is a petite tree found in Asia and belongs to the logania family or the 'Loganiaceae'. Vinblastine and vincristine are two more varieties of indole alkaloids that are found in the Madagascar periwinkle. These varieties also known as 'Catharanthus roseus' are commonly cultivated in the area as a bedding plant belonging to the dogbane family or the 'apocynaceae'. Commonly known as spindle poisonous, these alkaloids have proved to be very effective in the treatment of chemotherapy for patients suffering from leukemia as well as the Hodgkin's disease that refers to the 'lymph node and spleen cancer'. Researches have established (Obadoni and Ochuko, 2001) that this variety of alkaloids helps in terminating or 'depolymerization' of protein microtubules that form the mitotic spindle in cell division. This process efficiently helps in terminating the tumor cells from separating or dividing and, henceforth, resulting to reduction of cancer. Other spindle used by medical practitioners in cancer chemotherapy comprise podophyllotoxin. Podophyllotoxin is an antineoplastic glucoside obtained from rhizomes of many apple, scientifically known as 'Podopyhllum peltatum'. 'Podophyllum peltatum' belongs to the barberry family or 'Berberidaceae' and colchicines – an amine alkaloid from the corms of autumn crocus (*Colchicum autumnale*)

(Obadoni and Ochuko, 2001).

### 2. 1.3.4 Pyrrolizidine and quinolizidine alkaloids

Pyrrolizidine and quinolizidine are a complicated group. This group of alkaloids has always proven to be of immense pharmacological interest for researchers and clinical examiners. All these alkaloids are known to have lethal features and may prove to be fatal. While pyrrolizidine is obtained from omithine and is known to be injurious for the liver, quinolizidine is obtained from amino acid called lysine. Pyrrolizidine is generally found in ragworts, which is a problem for the grazing animals, comfrey, borage and coltsfoot. In the last instance, the evidence for toxicity is smaller and still unclear (Ajiwe *et al*; 2006).

#### 2.1.3.5Quinoline alkaloids

Quinoline alkaloids include two fold carbon rings comprising one nitrogen atom (N) and they include quinine from the bark of Cinchona ledgeriana. Incidentally, Cinchona ledgeriana is a South American tree in the coffee family (Rubiaceae). The alkaloid quinine is poisonous to Plasmodium vivax and three supplementary classes, including the single-celled organisms or protozoans that cause malaria. Malaria is certainly one of the most widespread ailments all over the humid expanses of the globe, and it is pread through the bite or blood meal of the female anopheles mosquito. Although many synthetic anti-malarial drugs such as atabrine, chloroquine and primaquine have been developed, currently, quinine trees are grown in plantations. Some species of plasmodium are opposed to many of the synthetic quinine analogues and hence natural quinine is still used even to this day. In fact, there are people who still take prophylactic doses of bitter quinine water (tonic) in the evenings, habitually mixed with vodka or gin (Ajiwe *et al*; 2006).

### 2. 1.3.6 Isoquinoline alkaloids

Isoquinoline alkaloids are associated with quinoline alkaloids and constitute an important division of the alkaloid family. Isoquinoline alkaloids can be divided into several sub-classes and among others, comprise elements such as simple isoquinolines, benzylisoquinolines, phthalideisoquinolines, protopines, morphine alkaloids, protoberberines and ipecac alkaloids. Simple isoquinolines are the alkaloids of mescaline cactus or Lopophora willamsii such as mescaline, while benzylisoquinolines are antecedents of many alkaloids that comprise opium poppy's papaverine. On the other hand, phthalideisoquinolines encompass all narcotine, protopines are restricted to the poppy family comprising protopine and protoberberines include berberine, hydrastine, canadine among others. Morphine alkaloids include morphine, codeine and the baine all from the opium poppy family, whereas ipecac alkaloids comprise emetic alkaloid, emetine obtained from ipecacuanha. Isoquinoline alkaloids comprise two-fold carbon loop that contains one nitrogen atom (N). This form of alkaloid comprises the narcotic alkaloids generally present in particular members of the poppy family or papaveraceae like the opium poppy or papave somniferum (Mark, 2003). All these powerful alkaloids are derived from the milk-like latex juice of ripened seed container of the opium poppy. Besides Papaver, opiate alkaloids that are found in the nature too are found in the argemone and dicentra genera. A major source of a

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powerful isoquinoline alkaloid utilized in curing deadly poisons is chondodendron

tomentosum, a member of the menispermaceae family, which is an extract from the barks and stem of a vine indigenous to South America. Indians in the Amazon area use this sticky derivative to cover the venomous nips of their blowguns – their amour against enemies as well as for hunting. Alkaloid D-tubocurarine posses a special healing power as it actively obstructs the acetylcholine receptor spots at the neuromuscular intersections enabling muscles to unwind as well as protect them from paralysis. This variety of alkaloid is also effective in relaxing as well as preventing the paralysis of the muscles in the respiratory tract as well as the heart. Significantly, D-tubocurarine alkaloids have been extensively used to unwind the muscles of the heart during open heart surgeries. In addition, this variety of alkaloid has also been used by medicos in curing spastic or convulsive paralysis of tetanus venom that causes unmanageable re trenchment of muscle all over the body (Mark, 2003).

## 2.1.3.7 Purine alkaloids

Purine alkaloids normally include caffeine, theophylline, theobromine and aminophyline which are obtained from cocoa, tea and coffee. These substances are collectively named xanthenes as they are obtained from the purine nucleotides adenine and guanine. They are medicinally beneficial as they are active in extending the effectual life of a number of hormones such as adrenaline (Mark, 2003). Purine alkaloids contain a molecular arrangement amazingly analogous to the nitrogenous purine base adenine that is generally present in DNA, RNA and ATP. Purine alkaloids comprise a two-fold carbon sphere containing four nitrogen atoms (N). Predominantly among the purine alkaloids are moderate invigorators like coffee or Coffea Arabica in the coffee species or rubiaceae. Tea or camellia sinensis in the tea family or theaceae, Yerba mate or Ilex paraguariensis a member of the holly species or aquifoliaeae, guarana or *Paullinia cupana* in the soapberry species or sapindaceae and cola or *cola nitida* in the chocolate species scientifically known as sterculiaceae. Incidentally, the most important origin of theobromine is from the seeds or beans of cacao scientifically known as Theobroma cacao. The Theobroma cacao is one member of the chocolate family that is called sterculiaceae (Mark, 2003). More than half of the world's coffee output comes not from Sri Lanka, but from South American nations such as Brazil and Colombia. The coffee fruits are plump berries, which comprise two seeds that are stuffed together in such a manner that the inner or adjoining sides of each of them are compressed. The coffee seeds, also known as coffee beans are isolated from the coffee cherries or berries and then roasted to prepare the coffee beverage. Coffee beverage is consumed in various forms and one of them is espresso coffee. Espresso coffee is generally prepared by passing steam through deeply roasted or dark-roast coffee beans (Mark, 2003). By removing caffeine from coffee beans or seeds one can prepare decaffeinated coffee. This can be done through either water extraction or solvent extraction of the coffee beans. Normally, in pure form, the coffee beverage is bitter to taste. There are a variety of coffees that comprise contaminants like ground chicory roots or cichorium intybus that actually lessen the unpleasantness in the beverage and enhance its essence. In the United States, chicory, belongs to the vast sunflower species that is scientifically known as asteraceae, are generally found along the roadsides and is common elsewhere too. Substitutes of coffee like the postum are also prepared from the molasses as well as the roasted muesli grains like wheat, barley and rye (Mark, 2003).

### 2.1.3.8 Functions of alkaloids in plant

The characteristic nature of alkaloids that often has pharmacological effects when administered to animals, naturally led scientists to speculate on their biological role in the plants in which they occur. In spite of many congestions over the years, however, little convincing evidence for their junction has been forthcoming.

- Being of such diverse nature, alkaloids as a group could not be expected to have a common role (if any) in the plant, except possibly in situations requiring a non-specific basic compound. In this respect the increase in putrescine in barley seedlings when grown in a medium deficient in potassium is of interest (Ajibola, 2004)
- 2. Alkaloids often occur in plants in association with characteristic acids for example, the tropane alkaloids of the solanaceae and erythroxylaceae are esters, the cinchona alkaloids occur with quinic and cinchotannic acids, opium alkaloids are associated with meconic acid. In some cases the alkaloids could provide either a means of storing or transporting in soluble form the particular acids. In the case of solanaceous plants it has been shown that tropane esters formed in the roots are translocated to the aerial parts, where hydrolysis of the alkaloid and breakdown of the liberated acid occurs.
- 3. As the majority of alkaloids are biosynthesized from readily available units by a series of ubiquitous reactions, their presence in the plant may be purely chemical, depending on the enzymes present and the availability of precursors. Being apparently harmless to the plant, they are not eliminated through necessity by natural selection (Ajibola, 2004)
- 4. By the use of suitable grafts, plants which normally accumulate alkaloids in the aerial parts (e.g. Nicotiana, Datura) are produced free of alkaloids. The lack of alkaloid in the

scion appears in no way to impair its development, which suggests the non-essential nature of the alkaloids.

- Plants which do not normally contain alkaloids appear usually to suffer no adverse reaction when administered alkaloids (colchicines is an exception). Some 'foreign' alkaloids may be metabolized.
- 6. Current research constantly demonstrates not only that alkaloids participate in plant metabolism over the long term, but also that daily variation in some species. This implies that even if the presence of alkaloids is not vital to the plant, they do participate in metabolic sequences and are not solely the waste, end products of metabolism.
- 7. Pertinent to the above, it has been suggested that alkaloids may have a role in the defence of the plant against singlet oxygen, which is damaging to all living organisms and is produced in plant tissues in the presence of light. Of fifteen alkaloids tested, most showed a good ability to quench singlet oxygen, with brucine and strychnine being especially efficient. Circumstantial evidence quoted is the turnover of poppy alkaloids on a diurnal basis and the formation of oxidized serpentine at the expense of the reduced ajmaline when catharanthus roseus tissue cultures are exposed to light. Further, to concur with the above hypothesis, one would expect plants inhabiting regions with a high ultraviolet light intensity to accumulate more alkaloids, and confirmatory examples quoted are berberine in berberis and tomatidine in lycopersicum. To these could be added quinine in cinchona.

### 2.1.3.9 Terpenoid Alkaloids

Terpenoid alkaloids are an assortment of amalgams or compounds that are obtained biosynthetically through different procedures that produce a number of groups of terpenes like sesquiterpenoids, monoterpenoids, terpenoid as well as steroids. Incidentally, this variety of alkaloids is found in irregular manner in the plant kingdom. For instance, the monoterpenoid alkaloids like gentianine are usually found in the plant family Gentianaceae. Resquiterpenoids, like dendrobine are generally found in the Orchidaceae or asinine in the Celastraceae, diterpenoids like aconitine are found in the anunculaceae family and steroidal alkaloids. Similarly, buxamine is found in screte plant families like Buxaceae, protoverine is located in the liliacea and planidine in the solanaceae. A number of terpenoid alkaloids also display anticedant and anti-fungal features. And most importantly, the fascinating alkaloids in this subgroup are present in the genus veratrum and they are normally beneficial for curing hypertension (high blood pressure), neuralgia as well as well as rheumatism (Ajibola 2004).

### 2.1.3.10 Importance of alkaloids

The importance of alkaloids in plants is not yet understood. It has been suggested that they are simply waste products of plants' metabolic processes, but evidence suggests that they may serve specific biological functions. In some plants, the concentration of alkaloids increases just prior to seed formation and then drops off when the seed is ripe, suggesting that alkaloids may play a role in this process. Alkaloids may also protect some plants from destruction by certain insect species. The medicinal properties of alkaloids are quite diverse. Morphine is a powerful narcotic used for the relief of pain, though its addictive properties limit its usefulness. Codeine, the methyl ether derivative of morphine found in the opium poppy, is an excellent analgesic that is relatively nonaddictive. Certain alkaloids act as cardiac or respiratory stimulants. Quinidine, which is obtained from plants of the genus cinchona, is used to treat arrhythmias, or irregular rhythms of the heartbeat. Many alkaloids affect respiration, but in a complicated manner such that severe respiratory depression may follow stimulation. The drug lobeline (from Lobelia inflate) is safer in this respect and is therefore clinically useful. Ergonovine (from the fungus Claviceps purpurea) and ephedrine (from Ephedra species) act as blood-vessel constrictors. Ergonovine is used to reduce uterine hemorrhage after childbirth, and ephedrine is used to relieve the discomfort of common colds, sinusitis, hay fever, and bronchial asthma (Ajibola, 2004). Many alkaloids possess local anesthetic properties, though clinically they are seldom used for this purpose. Cocaine (from Erythroxylon coca) is a very potent local anesthetic. Quinine (from Cinchona species) is a powerful antimalarial agent that was formerly the drug of choice for treating that disease, though it has been largely replaced by less toxic and more effective synthetic drugs. The alkaloid tubocurrarine is the active ingredient in the South American arrow poison, curare (obtained from Chondrodendron tomentosum), and is used as a muscle relaxant in surgery. Two alkaloids, vincristine and vinblastine (from Vinca rosea), are widely used as chemotherapeutic agents in the treatment of any types of cancer. Nicotine obtained from the tobacco plant (nicotiana tabacum) is the principal alkaloid and chief addictive ingredient of the tobacco smoked in bearettes, eigars, and pipes. Some alkaloids are illicit drugs and poisons. These include the hallucinogenic drugs mescaline (from Anhalonium species) and locybin (from Psilocybe mexicanna). Synthetic derivatives of the alkaloids morphine and lysergic acid (from C purpurea) produce heroin and LSD, respectively. The alkaloid coniine is the active component of the poison emlock (conium maculatum). Strychnine (from Strychnos species) is another powerful poison (Ajibola, 2004).

## 2.1.4 Wood Carbohydrates

Chemical analyses of wood hydrolyzates have been shown that the following simple sugars are present in wood:- D-glucose, D. mannose, D-galactose, D-xylose and tarabinose. Although it has been known for some time that each of these sugars occurs in wood in polymeric form quantitative determination is a recent development (Maton *et al.*, 1993) resulting from the discovery of paper chromatography and its application to sugar analysis by partridge.

Carbohydrates are common source of energy in living organisms; however, no carbohydrate is an essential nutrient in humans. Thus the name "carbohydrate" means a "hydrate of carbon" (Arun, 2000).

A carbohydrate is an organic compound with the empirical formula  $C_m(H_2O)_n$ ; it consists only of carbon, hydrogen, and oxygen, with a hydrogen: oxygen atom ratio of 2:1. Carbohydrates, which include cellulose, starches, sugars, and many other compounds, are the most abundant single class of organic substances found in nature. They are formed in green plants and certain bacteria by a process known as photosynthesis, in which energy derived from sunlight is used for the assimilation of carbon dioxide from the air. If carbon dioxide, water, minerals, and an appropriate inorganic source of nitrogen are available, these organisms, with the aid of solar energy, can synthesize all the different carbohydrates, proteins, and lipids they need for their existence.

Carbohydrates perform numerous roles in living organisms. Polysaccharides serve for the storage of energy, and as structural components in plants and arthropods. The 5-carbon monosaccharide ribose is an important component of coenzymes and the backbone of the genetic molecule known as RNA. The Saccharides and their derivatives include many other important biomolecules play key roles in the immune system, fertilization, preventing pathogenesis, blood clotting, and development (Maton *et al.*, 1993).

# 2.1.4.1 Nucleotides

Is a complex carbohydrate which contains many molecules of cyclic sugar. Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are complex five sided sugars classified under nucleotides. The difference between RNA and DNA is that RNA has one extra hydroxyl group (Arun, 2000).

# 2.1.4.2 Functions of carbohydrates

Carbohydrates are initially synthesized in plants from a complex series of reactions involving photosynthesis (Arun 2000). Carbohydrates perform various functions such as:

- i. Store energy in the form of starch (photosynthesis in plants) or (glycogen in animals and humans).
- ii. Provide energy through metabolism pathways and cycles.
- iii. Supply carbon for synthesis of other compounds.
- iv. Form structural components in cells and tissues
- v. Carbolydrates add on to the taste and appearance of food items, thus making the dish tempting and mouthwatering.
- vi. They are sometimes used as flavors and sweetners
- vii. Carbohydrates aid in regulating blood glucose and also break downfatty acids in the body, thus preenting ketosis

# 2.1.5 SAPONINS

The name saponin is derived from the Latin word 'sapo', which means the plant that consists of frothing agent when diluted in aqueous solution (Rigvera, 1997) Saponins are secondary metabolites found in natural sources; they are glycosides with a distinctive foaming characteristic. They consists of a polycyclic aglycone that is either a choline steroid or triterpenoid attached through C3 and an ether bond to a sugar side chain. The aglycone is referred to as the sapogenin and steroid saponins are called saraponins. Some saponins are toxic and are known as sapotoxin. The ability of a saponin to foam is caused by the combination of the nonpolar sapogenin and the water soluble side chain. Saponins are basically phytochemicals which are found in most of the vegetables, beans and herbs. The well known sources of saponins are soybeans, peas, and some herbs with the names that indicate foaming properties such as soapwort, soapberry, soapbark and soaproot. Commercial saponins are mainly extracted from Quillaja saponaria and Yucca schidigera. Saponins are bitter and reduce the palatability of livestock feeds. Some saponins reduce the feed intake and growth rate of nonruminant animals while others are not very harmful. In plants, saponins may serve as antifeedants and to protect the plant against microbes and fungi. Some plant saponins may enhance nutrient absorption and aid in animal digestion. However, saponins are often bitter to taste, and so can reduce plant palatability, or even imbue them with life-threatening animal toxicity.

#### 2.1.5.1 Sources of Saponin

Saponins have historically been understood to be plant-derived, but they have also been isolated from marine organisms (Rigvera; 1997). Saponins are indeed found in many plants (Liener, 1980), and derive their name from the soapwort plant (Genus saponaria, Family Caryophyllaceae), theroot of which was usedhistorically as a soap. Saponins are also found in the botanical family Sapindaceae, with its defining genus Sapindus (soapberry or soapnut), and in the closely related families Aceraceae (maples) and Hippocastanaceae (horse chestnuts). It is also found heavily in Gynostemma pentaphyllum (Genus Gynostemma, Family Cucurbitaceae) in a form called gypenosides, and ginseng or red ginseng (Genus Panax, Family Araliaceae) in a form called ginsenosides. Within these families, this class of chemical compounds are found in various parts of the plant: leaves, stems, roots, bulbs, blossom and fruit. Commercial formulations of plant-derived saponins, from the soap bark (or soapbark) tree, Quillaja saponaria, and from other sources are available via controlled manufacturing processes, which make them of use as chemical and biomedical reagents. Saponins are naturally occurring compounds that are widely distributed in all cells of trees. Saponins which derive their names from their ability to form stable soaplibe foam in aqueous solutions constitute a complex and chemical, diverse group of compounds. In chemical terms saponins contain a carbohydrate moiety attached to a triterpenoid or steroids. Clinical studies have suggested that saponins affect the immune system in ways to help to protect the human body against cancers and also lower cholesterol levels (Sodipo et al., 2000). A high saponin diet can be used in the inhibition of dental caries and platelet aggregation, in the treatment of hypercalcivria in humans and as an antidote against acute lead poisoning (Shi, 2004).

Saponins are present in most of the basic species.

### 2.1.5.2 Importance of Saponins

Saponins are found to have numerous health benefits. Recent studies have illustrated saponins' effects which have been beneficial on the control of blood cholesterol levels, bone health, cancer, and building up of the immune system. Saponin stromatolytic solution is being used for treating malaria. The utility of saponin is not only restricted to the comtemporary pramatalogy but it is also valued for its eco-friendliness. Saponin is used in treating pathogenic organisms present in agricultural crops as this colonizes the area of plant parts and tissues by controlling the level of toxic metabolites that are present in consumable products which derived from plant materials; this reduces the risk on health associated with the consumption of it. To kill

nematodes, employment of saponin is also being provided. By boiling a few soapnut shells for 5 to 10 minutes in a container of water, liquid soap can be made and can be used when cooled and even be refrigerated. This liquid soap solution can be used for washing pet's fur and skin as this removes parasites leaving the pet clean, soft and protected from any further infestations. This is an effective and economical household cleaner that cleans inside and outside of the house including kitchen and bathrooms, as well as the car. In India, it is used as a jewelry polish, by soaking jewelry into the liquid soap (Shi, 2004). Without using chemicals this liquid can be used to spray on plants. Sapindus mukorossi can be used as natural pesticide, as it produces saponins to repel insects. The most important advantage of using (Sapindus mukorossi) saponin is that it is a completely renewable, biodegradable material which can be put on to the compost heap once it gets spent. Saponin or Sapindus mukorossi is allergy free and is especially beneficial for babies and children who have a sensitive skin. People suffering from allergies and those who are suffering from dermatitis will be benefited if they use the liquid soap solution prepared from saponin (Shi, 2004). Among its benefits, saponin can also cure eczema. In addition, it is a very good detergent and is economical when compared to other normal chemical detergents, as it saves money for the fabric softener. It supports the local economy of the regions where it is being harvested. Many rural families worldwide often depend on the harvest of soap nuts (saponin) as it adds to their income. Saponin occurs in some ferns (species of Polypodium and Cyclamen) although they are predominant in angiosperms. They have been seeing occurring in some snake venom and marine animals as well. The antimicrobial and antibacterial properties of saponins have made them an important part and particle of human existence (Shi 2004).

#### 2.1.6 Glycosides

Glycosides are usually non-reducing compounds, on hydrolysis by reagents or enzymes yield one or more reducing sugars among the products of hydrolysis. Glycosides are compounds containing a carbohydrate and a noncarbohydrate residue in the same molecule. The carbohydrate residue is attached by an acetal linkage at carbon atom 1 to a noncarbohydrate residue or aglycone. The nonsugar component is known as the aglycone. The sugar component is called the glycone. The glycone can consist of a single sugar group (monosaccharide) or several sugar groups (oligosaccharide). If the carbohydrate portion is glucose, the resulting compound is a glucoside (Arun, 2000). Simply put, a glycoside is a molecule in which a sugar is bound to a non-carbohydrate moiety, usually a small organic molecule. Glycosides play numerous important roles in living organisms. Many plants store chemicals in the form of inactive glycosides. These can be activated by enzyme hydrolysis, which causes the sugar part to be broken off, making the chemical available for use. In formal terms, a glycoside is any molecule in which a sugar group is bonded through its anomeric carbon to another group via a glycosidic bond. Glycosides can be linked by an O-(an O-glycoside), N- (a glycosylamine), S-(a thioglycoside), or C- (a C-glycoside) glycosidic bond.

### 2.1.6.1 Classification of Glycosides

Glycoside can be classified on the bases of the following

# According to the Type of Glycosidic Linkage

Depending on whether the glycosidic bond lies "below" or "above" the plane of the cyclic sugar molecule, glycosides are classified as  $\alpha$ -glycosides ( $\alpha$ -sugar) or  $\beta$ -glycosides ( $\beta$ -sugar). Some enzymes such as  $\alpha$ -amylase can only hydrolyze  $\alpha$ -linkages; others; such as emulsion, can only affect  $\beta$ -linkages (Arun 2000).

### According to the Nature of the Simple Sugar Component of the

Glycoside:

- a. Glucosides (the glycone is glucose)
- b. Galacosides (the glycone is galacose).
- c. Mannosides (the glycone is mannose).
- d. Arabinosides (the glycone is arabinose).

#### According to the Physiological or Pharmacological Activity

Thereapeutic Classification):

- a. Laxative glycosides.
- b. Cardiotonic glycosides

### According to the correlation to the parent natural glycoside.

- a. Primary glycosides e.g. amygdalin, purpurea glycoside A,
- b. Secondary glycosides e.g., prunasin, digitoxin.

# According to the type of glycosidic bond: There are four types of linkages present between glycone and aglycone.

a. C-linkage/glycosidic bond,

- b. O-linkage/glycosidic bond
- c. N-linkage/glycosidic bond
- d. S-linkage/glycosidic bond

# According to the Chemical Nature of the Nonsugar component (Aglycone):

# Alcoholic Glycosides

An example of an alcoholic glycoside is salicin, which is found in the salix. Salicin is converted in the body into salicylic acid, which is closely to aspirin and has analgesic, antipyretic, and anti-inflammatory effects.

# Anthraquinone glycosides

These glycosides contain an aglycone group that is a derivative of imquinone. They have a laxative effect. They are mainly found in dicot except the liliaccae family which are monocots. They are present in rhubarb and Aloe species. Antron and anthranol are reduced forms of raquinone.

# 2.1.6.2 Properties of anthraquinone glycosides

The glycosides are extracted and hydrolyzed by boiling the drug with. The aglycones are extracted from the acidic solution with ether or benzene. Upon shaking the ether or benzene layer benzene layer with aqueous alkali or animonia solution, the aqueous layer assumes a deep red color, because of the nation of anthraquinone salts (Arun, 2000).

# 2.1.6.3 Cyanogenic glycosides

The aglycone in cyanogenic glycosides contains a cyanide group. All of these plants have these glycosides stored in the vacuole, but, if the plant is wacked, they are released and become activated by enzymes in the cytoplasm. These remove the sugar part of the molecule and release toxic hydrogen canide. Storing them in inactive forms in the cytoplasm prevents them from damaging the plant under normal conditions. They cyanogenic glycosides can also be found in the fruits of the rose family (including cherries, apples, plums, founds, peaches, apricots, raspberries, and crabapples) Cassava and Sorghum.

# 2.1.6.4 Flavonoid Glycosides

Here the aglycone is a flavonoid. Examples of this large group of consides include: (Edeoga *et al*; 2005).

- 1. Hesperidin (aglycone: Hesperetin, glycone: Rutinose)
- 2. Naringin (aglycone: Naringenin, glycone: Rutinose)
- 3. Rutin (aglycone: Quercetin, glycone: Rutinose)
- 4. Quercitrin (aglycone: Quercetin, glycone: Rhamnose)

Among the important effects of flavonoids are their antioxidant effect. They are also known to decrease capillary fragility.

# 2.1.6.5 Properties of Flavonoid Glycosides

(Edeoga et al; 2005)

- a. Flavonoids dissolve in alkalis give intense yellow color solution, on the addition of acid become colourless.
- b. Flavonoids exhibit strong fluorescence under UV light.
- c. Flavonoidal glycosides are soluble in water and alcohol. Ethylacetate is the solvent of choice for the extraction of flavonoids from aqueous solution.
- d. Flavonoids compounds may be characterized through the investigation of their UV Spectra, that usually show two main bands.
- e. Band at higher wavelength (band I) which is attributed to the cinnamoyl fraction of the flavonoidal structure.
- f. Band at lower wavelength (band II) which is due to the benzoyl fraction of the flavonoidal structure.

# 2.1.6.6 Phenolic Glycosides

Here the aglycone is a simple phenolic structure. When hydrolysed with loads or with emulsin it yields glucose and hydroquinone. An example is arbutin found in the common bearberry. It has a urinary antiseptic effect.

# 2.1.6.7 Saponins Glycosides

These compounds give a permanent froth when shaken with water. They also cause hemolysis of red blood cells. Saponin glycosides are found in quorice. The medicinal value is due to their expectorant, and corticoid and anti-inflammatory effects.

### 2.1.6.8 Steroidal Glycosides or Cardiac Glycosides

Here the aglycone part is a steroidal nucleus. These glycosides are found the plant genera Digitalis, Scilla, and Strophanthus. They are used in the treatment of heart diseases, e.g. congestive heart failure and arrhythmia.

### 2.1.6.9 Steviol Glycosides

These sweet glycosides found in the stevia plant have 40-300 times the sweetness of sucrose. The two primary glycosides, steviouside and rebaudioside are used as natural sweeteners in many countries. These glycosides have deviol as the aglycone part. Glucose or rhamnoseglucose combinations are found to the ends of the aglycone to form the different compounds.

# 2.1.6.10 Thioglycosides

These compounds contain sulphur. Examples include sinigrin, found in back mustard, and sinalbin, found in white mustard. Sinigrin gives upon hydrolysis, glucose, allylisothiocyanate solatile oil of mustard) and potassium acid sulphate while hydrolysis of the hycoside sinalbin gives a phenolic isothiocyanate (Acrinyl isothiocyanate), glucose and the acid sulphate of a quaternary alkaloid, sinapine (Arun, 2000).

#### 2.1.6.11 Sugars in Glycosides

(Trease and Evans 2002)
Monosaccharide (glucose in salicin, rhamnose in ouabain)
Disaccharides (gentiobiose in amygdalin)
Trisaccharides (strophanthotriose).
Tetrasaccharides (purpurea glycosides)
Rare sugars (deoxy sugers)
Sugar linked in one position to the aglycone rarely in 2 positions as sennosides.

### 2.1.6.12 Importance of Glycosides

- 1. Flavonoid glycosides Increase capillary resistance and decrease vitamins C & P deficiency.
- 2. Flavonoid glycosides are recommended in the treatment of thrombopenia.
- 3. These glycosides are used in the treatment of influenza, when given with ascorbic acid.
- 4. Saponins increases the rate of absorption of many pharmacologically active substances (e.g., cardiac glycosides).

- 5. Many saponin-containing drugs are used as expectorants (e.g., Ipeca, Senaga and liquorice) as their contents of saponins stimulate bronchial secretion and also activate the ciliary epithelium of the bronchi.
- 6. Saponin glycyrrhizin is use gastric ulcer treatment and have a cortisone like action in rheumatic arthritis and other inflammatory diseases.
- 7. Salicin is used for many years as a remedy in the treatment of fever and rheumatism.
- 8. Salicin is now used as an analgesic-antipyretic in case of periodic fever.
- 9. It is better tolerated in the stomach than sodium salicylate, asprin and other antipyretics and anti-inflammatory agents, which have largely displaced in medical practice.

### 2.1.7 PROTEINS

Proteins are essential nutrients for the human body. They are one of the building blocks of the body, but can also serve as a fuel source. As fuel, proteins contain 4 keal per gram, just like carbohydrates, and unlike lipids which contain 9 keal per gram. Proteins are biochemical compounds consisting of one or more polypeptides typically folded into a globular or fibrous form, facilitating a biological function. A polypeptide is a single linear polymer chain of amino acids bonded together by peptide bonds between the carboxyl and amino groups of adjacent amino acid residues. In nutrition, proteins are broken down in the stomach during digestion by enzymes known as proteases into smaller polypeptides to provide amino acids for the body, including the essential amino acids that cannot be biosynthesized by the body itself (Genton et al; 2010). Amino acids can be divided into three categories: essential amino acids, nonessential amino acids and conditional amino acids. Essential amino acids cannot be made by the body, and must be supplied by food. Non-essential amino acids are made by the body from essential amino acids or in the normal breakdown of proteins. Conditional amino acids are usually not essential, except in times of illness, stress or for someone challenged with a lifelong medical condition. Essential amino acids are leucine, isoleucine, valine, lysine, threonine, tryptophan, methionine, phenylalanine and histidine. Non-essential amino acids include alanine, asparagines, aspartic acid and glutamic acid. Conditional amino acids include arginine, cysteine, glutamine, glycine, proline, serine, and tyrosine. Unlike animals, plants do not, derive amino acids by consuming other organisms. Therefore, all 20 of these amino acids must be synthesized by the plant. A challenge lies in the fact that proteins have a finite life span and must be constantly translated from m-RNA in order for plant growth and development to continue. This means that there must be a ready supply of all 20 amino acids for protein synthesis and ultimately plant growth and development occur. Amino acids are found in animal sources such as meats, milk, fish and eggs, as well as in plant sources such as whole grains, pulses, legumes, soy, nuts and seeds.

# **2.1.7.1** Types of Proteins

A protein molecule that consists of but a single polypeptide chain is said to be monomeric; proteins made up of more than one polypeptide chain, as many of the large ones are, are called oligomeric. Based upon chemical composition, proteins are divided into two major classes: simple proteins, which are composed of only amino acids, and conjugated proteins, which are composed of amino acids and additional organic and inorganic groupings, certain of which are called prosthetic groups. Conjugated proteins include glycoproteins, which contain carbohydrates; lipoproteins, which contain lipids; and nucleoproteins, which are responsible for catalyzing the thousands of chemical reactions of the living cell; keratin, elastin, and collagen, which are important types of structural, or support, proteins; hemoglobin and other gas transport proteins; ovalbumin, casein, and other nutrient molecules; antibodies, which are molecules of the ummune system; protein hormones, which regulate metabolism; and proteins that perform mechanical work, such as actin and myosin, the contractile muscle proteins. (Wong *et al*; 2002)

## 2.1.7.2 Functions of Protein

- Antibodies are specialized proteins involved in defending the body from antigens (foreign invaders). One way antibodies destroy antigens is by immobilizing them so that they can be destroyed by white blood cells.
- b. Contractile Proteins are responsible for movement. Examples include actin and myosin. These proteins are involved in muscle contraction and movement.
- c. Enzymes are proteins that facilitate biochemical reactions. They are often referred to as catalysts because they speed up chemical reactions. Examples include the enzymes lactase and pepsin. Lactase breaks down the sugar lactose found in milk. Pepsin is a digestive enzyme that works in the stomach to break down proteins in food.
- d. Hormonal Proteins are messenger proteins which help to coordinate certain bodily activities. Examples include insulin, oxytocin, and somatotropin. Insulin regulates glucose metabolism by controlling the blood-sugar concentration. Oxytocin stimulates contractions in females.

#### **2.1.8 FIBRE**

Fibre is a class of materials that are continous filaments or are in discrete elongated pieces, similar to lengths of thread. They are very important in the biology of both plants and animals, for holding tissues together. Human uses for fibres are diverse. They can be spun into filaments, string, or rope, used as a component of composite materials, or matted into sheets to make products such as paper or felt. Fibres are often used in the manufacture of other materials. The strongest engineering materials are generally made as fibres, such as carbon fibre ultrahigh-molecular-weight polyethylene. Synthetic fibres can be produced very cheaply and in large amounts compared to natural fibres, for clothing natural fibres can give some benefits, such as comfort, over synthetic counterparts (Meyer, 1984).

### 2.1.8.1 Classification of Wood Fibre

## 2.1.8.2 Natural Fibres

Natural fibres include those produced by plants, animals, and geological processes. They are biodegradable over time. They can be classified according their origin.

- a. Vegetable fibres are generally based on arrangements of cellulose, often with lignin: examples include cotton, hemp, jute, flax, ramie, and sisal. Plant fibers are employed in the manufacture of paper and textile (cloth), and dietary fibre is an important component of human nutrietion.
- b. Wood fibre, distinguished from vegetable fibre, is from tree sources. Forms include groundwood, thermomechanical pulp (TMP) and bleached or unbleached kraft or sulphite pulps. Kraft and sulphite, also called sulphite, refer to the type of pulping process used to remove the lignin bonding the original wood structure, thus freeing the fibres for use in paper and engineered wood products such as fibreboard.
- c. Animal fibres consist largely of particular proteins. Examples are spider silk, sinew, catgut, wool and hair such as cashmere, mohair and angora, for such as sheepskin, rabbit, mink, fox, beaver, etc. (Meyer, 1984).

#### 2.1.8.3 Synthetic Fibres

Synthetic fibres generally come from synthetic materials such as chemicals, but some types of synthetic fibres are manufactured from cellulose, including rayon, modal, and Lyocell. Cellulose-based fibres are of two types, regenerated or pure cellulose such as from the cupronium process and modified cellulose such as the cellulose acetates.

Fibre classification in reinforced plastics falls into two classes: (i) short (also known as discontinuous) fibres, with a general aspect ratio ( ratio of fibre length to diameter) between 20 to 60, and (ii) long fibres, known as continous fibres; the general aspect ratio is between 200 to 500 (Meyer, 1984).

# **2.1.8.4** Cellulose fibres

Cellulose fibres are a subset of man-made fibres, regenerated from material cellulose. The cellulose comes from various source. Modal is made of beech trees, bamboo fibre is a cellulose fibre made from bamboo and made from seaweed. Bagasse is cellulose fibre made from sugarcane.

### 2.1.8.5 Microfibers

Microfibers in textiles refer to soluble fibre (such as polyester drawn to 0.5 m). Fibres refer to ultra fine fibres (glass or meltblown hermoplastics) often used in filtration. Newer fibre designs include extruding fibre that splits into multiple finer fibres. Most synthetic fibres are round in cross-section, but special designs can be hollow, oval, start-shaped or trilobal. The latter design provides more optically reflective properties. Synthetic textile fibres are often crimped to provide bulk in a woven, non woven or knitted structure. Fibre surfaces can also be dull or bright. Dull surfaces reflect more light while bright tends to transmit light and make the fibre more transparent. Very short and/or irregular fibres have been called fibrils. Natural cellulose, much as cotton or bleached kraft, show smaller fibrils jutting out and away from the main fibre structure.

Based on solubility, there are broadly two categories of fibre and we need to eat both in our daily diets:

- Soluble fibre includes pectins, gums and mucilage, which are found mainly in plant cells. One of its major roles is to lower blood cholesterol levels. Good sources of soluble fibre include fruits, vegetables, oat bran, barley, seed husks, flaxseed, psyllium, dried beans, lentils peas, soyamilk and soy products. Soluble fibre can also help with constipation.
- Insoluble fibre This includes cellulose, hemicelluloses and lignin, which make up the structural parts of plant cell walls. A major role of insoluble fibre is to add bulk to faeces and to prevent constipation and associated problems such as haemorrhoids (Meyer, 1984).

#### 2.1.8.6 Importance of Fibre

Fibre is essential to maintain optimum health; it keeps the bowels open and prevents constipation. It is essential in lowering blood cholesterol; and in keeping the digestive system healthy, Intake of fibre is a method of weight control.

### 2.2 WOOD PRESERVATIVE

There are different types of preservatives used in wood treatment, depending on the wood type and the end use of the timber. Chemical preservatives can be classified into three broad categories: water-borne preservatives, oil-borne preservatives, and light organic solvent preservatives (LOSPs).

#### 2.2.1 Water-Borne Preservatives

Water is the most common solvent carrier in preservative formulations due to its availability and low cost. Water-borne systems do however have the drawback that they swell timber, leading to increased twisting, splitting and checking than alternatives.

# 2.2.2 Chromate Copper Arsenate (CCA)

CCA preservatives are used to protect timber from all types of biological deterioration, including insect, termites, decay, and marine borers. In CCA treatment, copper is the primary fungicide, arsenic is a secondary fungicide and an insecticide, and chromium is a fixative which also provides ultraviolet (UV) light resistance and is recognized for the greenish tint it imparts to timber. In the pressure treatment process, an aqueous solution of CCA is applied using a vacuum and pressure cycle, and the treated timber is then stacked to dry. During the process, the mixture of oxides reacts to form insoluble compounds, helping with leaching problems. The process can apply varying amounts of preservative at varying levels of pressure to protect the wood against increasing levels of attack. Increasing protection can be applied (in increasing order of attack and treatment) for: exposure to the atmosphere, implantation within soil, or insertion into a marine environment. In the last decade concerns were raised that the chemicals may leach from the wood into surrounding soil, resulting in concentrations higher than naturally occurring background levels. A study cited in Forest Products Journal found 12-13% of the chromate copper arsenate leached from treated wood buried in compost during a 12-month period. Once these chemicals have leached from the wood, they are likely to bind to soil particles, especially in soils with clay or soils that are more alkaline than neutral. In the United States the US Consumer Product Safety Commission issued a report in 2002 stating that exposure to arsenic from direct human contact with CCA treated wood may be higher than was previously thought. On 1 January 2004, the Environmental Protection Agency (EPA) in a voluntary agreement with industry began restricting the use of CCA in treated timber in residential and commercial construction, with the exception of shakes and shingles, permanent wood foundations, and certain commercial applications. This was in an effort to reduce the use of arsenic and improve environmental safety (EPA,2004). In Australia, the Australian Pesticides and Veterinary Medicines Authority (APVMA) restricted the use of CCA preservative for treatment of timber used in certain applications from March 2006. CCA will no longer be used to treat wood used in 'intimate human contact' applications such as children's play equipment, furniture, residential decking and handrailing. Use for low contact residential, commercial and industrial applications remains unrestricted. In Europe, the use of arsenic, including CCA wood treatment has been restricted. CCA treated wood is not permitted to be used in residential or domestic constructions. It is permitted for use in various industrial and public works, such as bridges, highway safety fencing, electric power transmission and telecommunications poles. The CCA chemicals are designed to interact with wood constituents so that they fix in the wood and remain there for the life of the treated product. CCA is a clean, safe preservative. When used properly CCA is not a hazard to either users for the environment (Maton et al., 1993).

### 2.2.3 Alkaline Copper Quaternary

Alkaline copper quaternary (ACQ) is a preservative made off copper, a fungicide, and a quaternary ammonium compound (quat), an insecticide which also augments the fungicidal treatment. (Maton *et al.*, 1993). It is a wood preservative that has come into wide use in the USA, Europe, Japan and Australia following restrictions on CCA. Its use is governed by national and international standards, which determine the volume of preservative uptake required for a specific timber end use. The American Wood Protection Association (AWPA) standard for ACQ requires retention of 0.15 lb/ft<sup>3</sup> (PCF) for above ground use and 0.40 lb/ft<sup>3</sup> for ground contact. Since it contains high levels of copper, ACQ-treated timber is five times more corrosive to common steel. It is necessary to use double-galvanized or stainless steel fasteners in ACQ timber. The chemicals in ACQ products are also frequently used in products that are common in our every day lives. Copper, a naturally occurring mineral and the main ingredient in ACO, is an effective and widely used fungicide. Quaternary compounds (quats)
are commonly used in household disinfectants and cleaners and provide enhanced performance against copper-tolerant fungi and insects (http://www.tpaa.com.au/acq.htm). (Maton *et al.*, 1993).

### 2.2.4 Copper Azole

Copper azole preservative (denoted as CA-B and CA-C under American Wood Protection Association/AWPA standards) is a major copper based wood preservative that has come into wide use in Canada, the USA, Europe, Japan and Australia following restrictions on CCA. (Maton et al., 1993). Its use is governed by national and international standards, which determine the volume of preservative uptake required for a specific timber end use. Copper azole is similar to ACQ with the difference being that the dissolved copper preservative is augmented by an azole co-biocide instead of the quat biocide used in ACQ. The azole cobiocide yields a copper azole product that is effective at lower retentions than required for equivalent ACQ performance. The copper azole preservative incorporates organic triazoles such as tebuconazole or propiconazole as the co-biocide, which are also used to protect food crops. The general appearance of wood treated with copper azole preservative is similar to CCA with a green colouration. Other copper compounds include copper HDO (CuHDO), copper chromate, copper citrate, acid copper chromate, and ammoniacal copper zinc arsenate (ACZA). The CuHDO treatment is an alternative to CCA, ACQ and CA used in Europe and in approval stages for United States and Canada. ACZA is generally used for marine applications. (Maton et al., 1993).

## 2.2.5 Micronized Copper Technology

Particulate (micronized or dispersed) copper preservative technology has recently been introduced in the USA and Europe. In these systems, the copper is ground to micro sized particles and suspended in water rather than being dissolved in a chemical reaction as is the case with other copper products such as ACQ and Copper Azole. (Maton *et al.*, 1993). There are currently two particulate copper systems in production. One system uses a quat biocide system (known as MCQ) and is a take-off of ACQ. The other uses an azole biocide (known as MCA or  $\mu$ CA-C) and is a take-off of Copper Azole.Two particulate copper systems, one marketed as MicroPro and the other as Wolmanized using  $\mu$ CA-C formulation, have achieved Environmentally Preferable Product (EPP) certification. The EPP certification was issued by Scientific Certifications Systems (SCS), and is based on a comparative life-cycle impact

assessment with an industry standard. The copper particle size used in the "micronized" copper products ranges from 1 to 700 nm with an average under 300 nm. Larger particles (such as actual micron-scale particles) of copper do not adequately penetrate the wood cell walls. These micronized preservatives use nano particles of copper oxide, for which there are alleged safety concerns. (Maton *et al.*, 1993).

## 2.2.6 Borate Preservatives

Boric acid, oxides and salts (borates) are effective wood preservatives and are supplied under numerous brand names throughout the world. Borate treated wood is of low toxicity to humans, and does not contain copper or other heavy metals. However, unlike most other preservatives, borate compounds do not become fixed in the wood and can readily be leached out. Therefore they should not be used where they will be exposed to rain, water or ground contact. Recent interest in low toxicity timber for residential use, along with new regulations restricting some wood preservation agents, has resulted in a resurgence of the use of borate treated wood for floor beams and internal structural members. (Maton *et al.*, 1993).

# 2.2.7 Sodium silicate – based preservatives

Sodium silicate has been in use since the  $19^{th}$  century. It is produced by fusing sodium with sand or heating both ingredients under pressure. It can be a deterrent against insect attack and possesses minor flame-resistant properties; however, it is easily washed out of wood by moisture, forming a flake-like layer on top of the wood. Timber Treatment Technology, has found that infusing timber with a chemical solution containing sodium silicate with a specified energy level applied, yields wood that does not provide flake or layering on the wood, nor wash out as others have done in the past; but provides processed umber that received a class A fire classification (Maton *et al.*, 1993).

# 2.2.8 Potassium silicate-based preservatives

There are a number of European natural paint fabricants that have developed potassium silicate (potassium waterglass) based preservatives. They frequently include boron compounds, cellulose, lignin and other plant extracts. They are a surface application with a minimal impregnation for internal use (Maton *et al.*, 1993).

### 2.2.9 Bifenthrin spray preservatives

In Australia, a water-based bifenthrin preservative has been developed to improve the insect resistance of timber. As this preservative is applied by spray, it only penetrates the outer 2 mm of the timber cross-section. Concerns have been raised as to whether this thin-envelope system will provide protection against insects in the longer term, particularly when exposed to sunlight for extended periods. (Bill-Meyer, 2003).

### 2.2.10 Fire retardant treated wood

This treated wood utilizes a fire retardant chemical (example formaldehyde) that remains stable in high temperature environments. (Bill-Meyer, 2003). The fire retardant is applied under pressure at a wood treating plant like the preservatives described above, or applied as a surface coating.

## 2.2.11 Oil-born preservatives

These include pentachlorophenol and creosote. They are toxic, have an unpleasant odour and are generally not used in consumer products.

# 2.2.12 Coal-tar creosote

Creosote is a tar-based preservative that has been commonly used for telephone roles and railroad ties (http://www.tpaa.com.au/creosote.htm). Creosote is one of the oldest wood preservatives, and was originally derived from a wood distillate. These days virtually all creosote is manufactured from the distillation of coal tar. It often collects inside chimneys and may cause a fire hazard. Creosote is regulated as a pesticide. It is still used for railroad ties and utility poles. It is a deterant against insect attack and possesses flame retardant property.

# 2.3 FATS AND OIL

The term oil denotes material substances that are extracted from the cells and organic tissues of plants and animals. They are also known as viscous combustible liquid that are insoluble in certain organic solvent such as alcohol, ether, benzene e.t.c. There are various categories of oils amongst which are petroleum shale and other oils. (A.O.C.S,1960). Fixed oils depicts various compounds of glycerin and different complex fatty acids respectively. Oils are analogous to fats in chemical composition and occur naturally as triglyceride which is the esters of glycerol with saturated or unsaturated fatty acid. They have a general formula: R<sup>I</sup>OOC-C<sub>2</sub>H -CH, OOR<sup>I</sup>

<sup>I</sup>, CH<sub>2</sub>OOCR<sup>III</sup>, R<sup>I</sup>, R<sup>II</sup> and R<sup>III</sup>. This indicated that about three different species of acids are present. Fixed oil is usually referred to as non volatile oil and is readily vaporized by heat. Sometimes, fixed oil are usually characterized by a spit when dropped on a paper, most of them are liquid at 100°C while others are solid at the temperature of 200°C. Consequently, the solid form designates fats, though; most of the fats undergo a change from solid to liquid and vice versa on a slight change in temperature (Ajiwe et al., 2004., Nwafor, 1995). Fixed oils are sourced mainly from the seeds of plants. Fixed oils can be obtained from the vegetable tissues but this requires lots of techniques. The commonly used technique is that in which the seeds obtaining the oils are usually subjected to great and intense pressures. This can be done without necessarily applying heat but is more frequently facilitated and hot-pressed instead of coldpressed. (American Society for Testing and Material, 1985), At present, the machine press method is preferred and is widely in use. This particular machine press has a rotating screw, whose function is to press the ground seals under high pressure through a large cylinder. The oil is therefore squeezed through the openings in the cylinder. This procedure has a comparative advantage over the other method because it is continuous and the machine need not be stopped from loading. The third method of obtaining the oil from the plant tissues is by employing various methods of refining deodorization and deoxidation respectively. Alternatively, the soxhlet-solvent extraction method is applicable using petroleum ether (60-80°C) followed by the expression of oil from the plant tissues. Oils are classified into four group namely drying, semi-drying, none drying and vegetable oils. Drying oils refer to those which on exposure to air form a tough elastic film. Their iodine values are normally above 130. They contain unsaturated acid like anoleic acid. Examples of such oils are tung oil and linseed oil. They are used for making paints. Non-drying oils denote those oils that do form films on exposure to air and remain liquid at ordinary temperature. They have high content of oleic acid and have iodine value too. They are generally edible. Examples of non-drying oils are castor oils, cocoa butter, melon, and coconut as well as teas seed. Semi drying oils are intermediate in nature between non-drying oils and drying oils. Their iodine value range is 90-140. The principal semi-drying oils are cotton seed oil, Soya bean, corn oil and Pachystela brevipes seed oils etc. Drying and semi-drying oil belong to the group of oils often classified as hard and soft oils. The drying oils are hard oils, while semi-drying oils are soft oils, Fats and oil play vital roles in industrial production of paints, liquid soap, shampoo, varnish, and polish, binders in paints, plasticizers for plastics, paints, and cosmetics, textile, paper and lubricants (Ajiwe et al., 1995., Nwafor, 1995., Ajiwe et al., 1996., Njikan, 1995).

#### CHEMICAL CHARACTERIZATION OF OIL EXTRACTED FROM WOOD

## 2.3.1 IODINE VALUE

This is indicates the main unsaturation present in the oil and usually expressed as the number of grams of iodine absorbed by 1.0g of oil. The higher the unsaturation of the oil, the better the drying quality of the oil (Kirk, 1965)

# 2.3.2 Saponification value

This is determined as the number of milligram (mg) of potassium hydroxide (KOH) required changing 1g of fat completely to glycerol and the potassium soap. Oils that are composed of long chain, high molecular weight fatty acids have low saponification number while low molecular weight short chain fatty acids have high acid value (American society for testing material, 1985. (Spammuth, 1949).

# 2.3.3 Acid value

This is defined as the number of milligram of potassium hydroxide (KOH) required neutralizing the free fatty acid present in 1g of sample. It is also a measure of the amount of free acid present in an oil or fat sample (Bernfeld, 1987).

# 2.3.4 Fatty Acids

This denotes a large group of aliphatic monocarboxylic acid occurring mainly in glyceride in natural fats and oils. The general formula of fatty acid is as follows



Which indicated that carboxyl group;-COOH is attached to a radical that consists of an open chain of carbon atoms, which may either be saturated or unsaturated with respect to hydrogen. With regards to unsaturated acids beside the chemical formula, the position of the double bonds is equally indicated by the position of the preceding carbon atom as in linoleic and oleic acids. In most fat, about two or three categories of fatty acids exist: the mixed fatty acid which consists of normal straight chain and the unsaturated acid with an even number of carbon atom, that is,  $C_6O_{24}$  per molecule. They can be saturated or unsaturated and can be used as food. The unsaturated fatty acids are mainly limited to those having one, two or three double bonds, for example: linoleic, oleic etc. Those with more than one double bond normally have them in the

isolated position in which a  $CH_2$  interposed. Consequently, in saturated series, myristic, palmatic, stearic and lauric are the most wide spread. Generally, the proportion of different kinds of fatty acids, depend on the length of the molecules, geometric isomerism in the unsaturated acids, degree of unsaturation and the position of the double bonds with respect to carboxylic groups and to each other respectively. But when there is a substituting group, such also influence in the property of the acid. (A.O.C.S, 1990, Kirk,1965). Fats and Oils are lipids, which are the naturally occurring compound which is soluble in organic solvent but sparingly soluble in water. They are compounds of glycerol and various organic acids and they occur in the proportion of approximately 95% fatty acid and 5% glycerol respectively; they are therefore termed glycerids or glyceryl ester. Oils are unsa turated while fats are saturated. So, a typical molecule has the structure below, in which R, R<sup>1</sup>, R<sup>11</sup> indicate long saturated chains (A.O.C.S, 1960., Bernfeld, 1987).

$$\begin{array}{c}
0\\
||\\
CH_2-O-C-R\\
|\\
0\\
|\\
CH-O-C-R'\\
|\\
0\\
|\\
|\\
CH_2-O-C-R (Fats or Oil)
\end{array}$$

The fatty acids radical constitute the greater part of the glycerol molecule and the reactive portion, hence the chemical and physical properties of oil determined by the properties of its component fatty acids. The chief saturated acids are myristic, stearic and lauric acids. On the other hand, the chief unsaturated are oleic and linoleic. Palmatic acid is the most abundant of the saturated acid such as palm oil. Glycerids are named according to the nature of the acids present and it is said to be simple when all the acid are the same and mixed when the acids are different, for example, steroid. Animals and vegetable fats are mainly composed of triglycerides of fatty acids such as stearic, palmitic and oleic, a molecule of such a triglyceride being derived by the combination of one molecule of glyceride; three fatty acid molecule. When the average molecular weight of the fatty acid increased, fats progressively have melting points and more easily solidifies. (A.O.C.S., 1960., Lillian, 1982).

		CH <sub>2</sub> OCOC <sub>15</sub> H <sub>31</sub>
		CHOCOC <sub>17</sub> H <sub>35</sub>
		CH <sub>2</sub> OCOC <sub>17</sub> H <sub>33</sub>
$CH_2OCOC_{17}H_{35}$		(Mixed Glyceride)
(Single Glyceride)	-	

Fatty oils are sometimes called "fixed oils" so as to differentiate them from volatile or essential oils. Fats that occur naturally contain small amount of phospholipids such as lecithin, cephalin and sphingomycin in which glycerol, fatty acid, phosphoric acid and nitrogen bas e are combined. Associated with phospholipids are glycolipids, which are carbohydrate, fatty acid compounds which contain nitrogen but no phosphoric acid. Large quantity of fats is consumed as naturally fatty food and many edible prepared fats producs respectively. It serves as the most concentrated to 4.ikcal/g from protein and carbohydrate. It is used as the major source of fatty acid in the manufacture soap and many other surfaces-active materials (Njikan, 1995; Apsimon, 1981).

## 2.3.5 Physio-Chemical Characteristics and Applications of Oils

Fats and oils have specific physical and chemical characteristics, which vary within a limited range. They are insoluble in water, but soluble in most organic solvent like petroleum ethern, chloroform, carbon disulphide and ethyl ether, they are slightly soluble in alcohol except castor oil which is readily soluble in alcohol. The application of fats and oils in industries is determines by certain physiochemical constants such as saponification values, iodine value and acid value respectively which gives vital information about their physical and chemical characteristics. Oil can be analyzed for composition characteristics and nutritional values and keeping quality of the oil can be assessed in terms of the physio-chemical analysis. While its utilization can be determined from its composition and physio-chemical properties. The various sampling methods of fats and oils and the analysis of commercial fats and oils have been given by the Institute of petroleum (IP), (ASTM,1983., A.O.C.S, 1960., van-Nostrand,1976 and Krishna, 1980). Basically, it should be noted that oils with iodine value 80-100, are no-drying oils. Those with 100-200, are semi-drying oils while those with iodine value above 180, are drying oils.

#### 2.3.6 Industrial Uses of Oil

Fats and oil serve as the most important raw materials in industrial production of various products such as soap, cream, lotion, cosmetics, varnish, binders in paints, paints, plasticizers for plastics etc. they give palatability to food and serve as essential emulsifier for a number of drug preparations. The bulk of fats and oil is used for cooking. Some oil serves as essential food and as solvents in the preparation of intramuscular injection. (Kerkof , 1990, Ajiwe *et al.*, 1996).

### 2.3.7 Oil in Food Industry

In food industry, vegetable oils undergo further processing to jettison pigment by absorption. Tight saponification mechanism is employed in the removal of free fatty acid while volatile odors-causing components are removed by steam distillation under reduced pressure. Olive oil usually undergoes minimal processing because of the priced uniqueness of its flavour. All the toxic polyphenolic component of cotton seed oil should be removed. Silicon is added sometimes to drive away or eliminate framing (Lillian,1982., Rajelson *et al.*, 1980., Krishna, 1980., Kirchmann *et al.*, 1996).

#### 2.3.8 Oil in paint Industry

Some drying oils such as linseed, Tung and dehydrating castor oil have direct use as binders in paints, varnishes, and enamel and painting inks. They are also used as modifying agents for a number of polyamine paint binder such as polyesters (alkyds). The modifies alkyds resin possesses unsaturated fatty acid. Segment along its chain, 60-805 oil are used primarily as binders for decorative finishing paint system. The glycerol incorporated in the manufacture of alkyds is itself a bye product of fats and oil (A.O.C.S, 1960, VanNostrand, 1976; Fregley,1982).

#### 2.3.9 Oil in Rubber Industry

Softeners are added to facilitate the addition and dispersion of the other solid compounding ingredients as well as to enhance the processing properties for extrusion, calendaring etc. tack (stickiness) is another property achieved by adding softeners and it is essential for many applications such as tyre building. Vegetable and petroleum oils are used as softeners (A.O.C.S, 1960; Kirk, 1965).

# 2.3.10 Oil in Plastic Industry

Oil products are used as plasticizers for plastics. Plasticizers are non-volatile materials added to high polymers to soften and render them plastic or flexible during processing or to impart permanent flexibility and rubber- like extensibility. Blown oils, obtained by bubbling air through a drying oil at temperature of 82-110<sup>o</sup>C have good compatibility with nitrocellulose and are used extensively as plasticizers for it. Other oil-based plasticer includes oleates and epoxy plasticizers produced by reacting hydrogen peroxide with unsaturated vegetable oil and fatty acids. (A.O.C.S 1960; Fregley,1982).

### 2.3.11 Oil in Pharmaceutical Industry

Fats and oil are used as solvents in the preparation of intramuscular injections, for example, sesanine oil; other has medicinal actions, for example; castor oil as (catharric,), cod liver oil (as an anthracitic) and olive oil (as emollient). Lecithin is used as an emulsifier, antioxidant and stabilizer in food and pharmaceutical preparation respectively

## 2.4 PROXIMATE ANALYSIS

The factors that are often analyzed include the following such as: ash, crude fiber, crude protein, crude fat, moisture content and carbohydrate. Using the standard method of analysis of AOAC (1980) and Lillian's method (Lillian, 1982).

# 2.4.1 Ash content

This is mineral left behind after the organic mattes such as the protein, sugar, fats etc have been burnt. Determination if ash is essential in formulation if feed nutritional value (Van-Nostrand, 1976., Krishna, 1980).

## 2.4.2 Crude fibre

Crude fibre is the organic residue, which remains after the material has been treated under standardized condition with light petroleum, boiling with dilute sulphuric acid, boiling with dilute sodium hydroxide solution and neutralizing with alcohol and water. The crude fibre consist largely or cellulose with lignin, which could be determined by using standard method. The amount of crude fibre in any material gives the indication of the quantity of food material in terms of starch. The higher the crude fibre value the lower the quantity of starch (Rajelson *et al.*, 1980).

# 2.5 Moisture content

Moisture content determination is essential in feeds storage. The safe limit for storage is 15% moisture, Feed stuffs that contain more than 15% moisture should not be stored; this is because it may develop the undesirable moulds and fungus. In determination of moisture content, temperature variation plays an important role. The even temperature and the temperature and duration of drying is in relation to the nature of the samples. It is not only the water that is expelled, it involves volatile matter, thereafter, a suitable drying operation that ensure the

nearest elimination of moisture without burning the test sample is adopted using temperature of  $105^{\circ}C^{3}$ .

# 2.5.1 Body usage of mineral

Minerals are necessary for body metabolism; they help in adding mechanical strength to bones. They are a component of enzymes and hormones and functions as buffers and regulate the balance and improvement of fluid in and out of cell.

# 2.5.2 Identification of Minerals

Some minerals that have been identified as being essential to the physical well being of human and animals are known to be thirteen in number. They include sodium, iron, potassium, magnesium, calcium, iodine, cobalt, copper, manganese, and zinc.

In addition to this, there are trace minerals which are essential elements that occur in minute amounts. The deficiency results of minerals especially the rare trace minerals are the largest cause of physical problems of aging (Van Nostrand, 1976; Maynard, 1970).

# 2.5.3 Importance of the Minerals

## 2.5.4 Sodium

Sodium plays an important role in electrolytic metabolism. It works with potassium to equalize the acid alkaline balance of the blood and water balance in the body as well as the transportation of nutrients into the body cells and waste products out of the body cells muscle contraction and move nerve stimulation.

## 2.5.5 Potassium

Potassium is associated with sodium metabolism. In the correct ratio, odium and potassium regulates water balance in the body.

# 2.5.6 Zinc

Zinc is found in all tissues, its function include enhancing the immune system, specifically the thymus gland and spleen involvement and in the Krebs's cycle and energy production. It protects against birth defect. Zinc can also prevent toxemia; parakeratosis.

## 2.5.7 Iron

Iron is a constituent of hemoglobin; it is an integral component of hemoglobin which transports systems for energy production and metabolism (Maynard,1970., Fregley, 1982).

# 2.5.8 Cobalt

This functions as a component of vitamin B12 molecule and is necessary in the remen synthesis of vitaminB12. Deficiency leads to loss of appetite, emaciation, restlessness, macryotic-anaemia and in coordination.

#### 2.5.9 Magnesuim

It is necessary for many enzymes. It helps in carbohydrates metabolism and is necessary for the function of nervous system. Deficiency results to hypo magnesis associated with toxic symptoms and frequently death. Excess of it causes depression of cardiovascular system (Maynard, 1970; Bernfeld, 1987).

### 2.6 Wood and its uses

Wood is a hard fibrous tissue found in many plants. It is a heterogeneous plant material as it is composed of four different kinds of elements, namely, tracheids, vessels or tracheae, wood fibers and wood parenchyms. These wood elements are composed of cells and the cell walls are made up of microfibrils of cellulose (40 - 50%), hemicelluloses (15 - 35%) lignin (15 - 50%)25%) and other extractives (Rowell et al., 2005). The cellulose and hemicelluloses constituents of wood make it hygroscopic. Being of biological origin, wood have been shown to be anisotropic as there are diversity and variations between and within different species of trees. The fundamental structure i.e. from the molecular to cellular or anatomical level influences the properties and behavior of wood. Wood is used as a source of fuel, especially in rural areas of the world. It is used in construction houses, boats, bridges, boxes, cabinets, and doors. In the last decade, alternative building materias have begun to gain prominence due to environmental concerns, durability issues and conceptions about the consequences of building with wood. Untreated wood is completely renewable, serves as a great insulator, uses less energy to process than steel, concrete, aluminium or plastic and is completely renewable. It is also cost effective, aesthetically pleasing and environmentally responsible. Wood unsuitable for construction in its native form has been broken down mechanically (into fibre or chips) or into cellulose and used as raw material for other materials as chipboard, hardboard, paper, laminate flooring. Wood has been proposed as the alternative for petrochemicals, since it provides lignin-based chemicals that can be used for lignin-glues, recyclable, food packages, rubber tyre replacements, bacterial medical agents and high strength fabrics or composits. Recently, some Italian screntists harnessed the use of wood, specifically rattan wood, in the medical treatment of animal bone as a substitute (Rowel *et al*; 2005)

## 2.6.1 Chemical Properties of Wood

Important chemical properties for combustion are the ultimate analysis, proximate analysis, analysis of pyrolysis products, overall heating value. Heat of pyrolysis, heating value of the volatiles, and heating value of the char. The ultimate analysis provides weight percentage of C, H, O, N, and S. The C content of softwood species is 50-53%, and that of hardwood species 47-50% due to the varying lignin and extractives content. All wood species contain about 6% H (Petura, 1979). Proximate analysis gives the weight fraction of moisture, and volatiles including tar, char, and ash. According to ASTM standard test method E870-82. The volatile yield of dry wood depend on the temperature and heating rate of pyrolysis. The tar has an average composition (Adams, 1980) of  $C_6H_6.2CO_2$ , and the light hydrocarbons are primarily methane. The higher heating value of different wood species on a moisture-free basis varies less than 15%. The higher heating value of softwoods is 20-22 MJ kg<sup>-1</sup> and of hardwoods, 19-21 MJ kg<sup>-1</sup>. Typically, softwoods have more extractives and more lignin than do hardwoods, which accounts for the slightly higher heating value.

### 2.6.2 Ash Content

Ash is a solid, particulate, inorganic combustion residue left after the wood is burnt. Ash content varies between different component of trees. Stem wood contains 0.4 - 0.6% stem bark 2.0 - 5.0% and 1.0 - 2.0% in branches. The ash content is highest in those parts of the tree where growth occurs.Wood ash has the following elements Carbon (5 % to 30 %), Calcium (5 % to 30 %), Potassium (3 % to 4 %), Magnesium (1 % to 2 %), Phosphorus (0.3 % to 1.4 %), Sodium (0.2 % to 0.5 %). (Van-Nostrand ,1976).

### 2.6.3 Thermal Properties

Important thermal properties in the analysis of wood combustion include the specific heat of wood and char, the thermal conductivity of wood and char, and the emissivity of char. Specific heat depends on temperature and moisture content but not on density or species. The specific heat of dry wood is given by

 $c(dry) = 0.1031 + 0.003867T (kJ kg^{-1} K^{-1}) (1)$ 

The specific heat of wet wood is greater than would be expected from the simple law of mixture as a result of the energy absorbed by the wood-water bonds and can be represented by a Correction term

c(wet) = [c (dry) + 4.19 M]/(1+M) + A (kJ kg-1 K<sup>-1</sup>) (2)where

A = (0.02355T - 1.32M - 6.191) M,T = temperature in K, and M = fractional moisture content dry basis. The thermal conductivity of wood increases with density, moisture content and temperature.

## 2.6.4 Mineral Properties

The mineral content of clean wood of temperate tree species is 0.1% to 06% and that of bark 3% to 5%. Mineral matter in wood consists mostly of salts of calcium, potassium, and magnesium. But salts of many other elements are also present in lesser amounts. Some salts are formed with the organic acid groups of the cell wall components. Whereas others occur as carbonates. Phosphates, sulfates, silicates and oxalates. The mineral content of wood and bark is highly variable between and within species and can vary with soil and growth rate. Ash is formed from mineral matter during combustion and gasification. The ash yield of wood grown in the temperate zones is 0.1-1.0%, whereas wood grown in the tropics contains up to 5% ash (Fengel & Wegener, 1984). Bark contains 3-8% ash. Wood ash typically includes 40-70% calcium oxide and 10-30% potassium oxide.

# 2.6.5 NIGERIAN VEGETATION:

In Nigeria, there are five different types of vegetation namely:

- I Mangrove and fresh water swamp forest
- ii The rain Forest
- iii Guinea savannah
- iv Sudan savannah
- v sahel savannah

The mangrove and fresh water swamp forest covers the delta area of the country.

The rain forest covers the savannah half of the country (Ogun, Oyo,Ondo, Delta and Anambra state as well as Imo, Rivers, Akwa Ibom and Cross River State).

The Guinea Savannah covers the upper parts of Anambra, Oyo, Ogun, Ondo, Kwara and Benue states.

Sudan savanna covers Sokoto, Kastina, Kaduna, Niger, Plateau, Gongola and Bauchi Sahel savannah covers North East corner of Kano, Brono States, (Balogun and Ajayi, 2006).

# 2.7 NAMES AND DESCRIPTION OF TREES SELECTED FOR INVETSTIGATION

## 2.7.1 Annona senegalensis

Scientific classification: It is a hardwood (angiosperm) from the plant kingdom and belongs to the Family of *Annonaceae*, in the Genus of Annona.

Annona senegalensis, commonly known as African custard-apple, Wild custard apple, and wild soursop, is a specie of flowering plant of the custard apple family, Annonaceae. The specific epithet, senegalensis, translates to mean "of Senegal", the country where the type specimen was collected. A traditional food plant in Africa, the fruits of A. *senegalensis* have the potential to improve nutrition, boost food security, and foster rural development and support sustainable care.

# 2.7.2 Brachystegia nigeria

*Brachystegia* itself is a genus of tree of the sub-family *Caesalpinioideae* that is native to tropical Africa. Trees of the genus are commonly known as Miombo, and are the predominant tree in the Miombo woodlands of Central and Southern Africa. *Brachystegia nigeria* is a species of legume in the Fabaceae family. It is found in Cameroon and Nigeria. It is threatened by habitual loss.

# 2.7.3 Sterculia oblonga/Cola gigantia

This is commonly known as Eyong (River State), though it has other names like Ebenebe (Ibo) and Okoko (trade name).

## Uses

It is used as veneer for back or face of plywood. Used for furniture making. Can also be used for flooring. **Wood description:** It has a light yellow colour, its sapwood is not clearly demarcated. Its texture is medium, while its grain is straight or interlocked.

# 2.7.4 Lophira alata

This plant is commonly known as Azobe, from the family of *Ochnaceae*. Wood Description: The wood from this plant is dark red colour in appearance. It's sapwood is clearly demarcated. Generally, the woods have a coarse texture, drying: It has a slow drying rate, high risk of distortion as well as a high risk of checking.

Uses: This wood can be used for the following: Hyraulic works (fresh and sea water) Making of sleeper and stairs (inside) Construction of bridges (parts in contact with water or ground) Heavy carpentry works Wood frame house works Can also be used in making of stakes, posts, and cooperage.

# 2.7.5 Irvingia gabonensis

*Irvingia gabonensis* is a tree, native to West Africa. The fruit is similar to a mango and is used for food. The seeds are used to make medicine.

It has other names like: African Mango, Ogbono (*irvingia wombulu*) or Ugiri(*irivingia gabonensis*), Bread Tree, Bush Mango, Dika Nut, Dilanut, Dikka, Duiker Nut, Etima, Irvingia, *Irvingia barteri, Irvingia gabonensis, Kaka mangife* a gabonensis, Manguier Sauvage, Odika, Ogbono, Wild Mango.

Uses: Generally, they can be used for several purposes such as: in pharmaceuticals.

There is interest in using supplements containing Irvingia gabonensis for weight loss, lowering cholesterol levels, and improving control of diabetes.

They can also be used for construction works due to its hard nature.

Irvingia is named after Dr. Irving, R. N., who died at Abeokuta (Keay *et al.*, 1964). Irvingia *gabonensis*, the wild mango or duka nut, with mango like edible fruits may be readily recognized by its dense dark green evergreen foliage and characteristics stipules. It is of the forest habitat and tree to 24 m high and 1.8 m in girth, occasionally more, with a dense compact crown. The bole is usually rather fluted and slightly buttressed. The bark is grayish, smooth or

very slightly scaly; slash yellow brown to light yellow, and brittle stipule curved, the one terminating the shoot up to 2.5 cm long, the others smaller. Figure 4 shows the bole of Irvingia gabonensis in Omabala forest at Ifite Ogwari in Ayamelum L.G.A. of Anambra State.

The leaves are 5-15 cm long by 2.5-6 cm broad, elliptic to slightly obovate, one margin often a little more rounded than the other, acute or shortly acuminate, cuneate or slightly rounded at the base; leathery, dark green and glossy above. The leaves have 5-10 pairs of irregular lateral nerves, the lower ones running out vaguely to the margin, the upper ones looped, minor nerves more or less parallel and at right angles to the laterals. The veins form a close network between and stalk is stouty, about 0.6cm long.

# 2.7.6 Albizia ferruginea

This wood is commonly known as latandza from the family of the Mimosaceae. Its other names are: Ngwu (Ibo), Okuro(Ghana), and Ayinre-ogo (Nigeria).

Wood Description: The wood is red brown in colour, with a clearly demarcated sapwood. It has an interlocked grain.

Drying: Its drying rate is slow, having a high risk of distortion. It has a slight risk of checking. Uses:

Used as veneer for interior and bark or face of plywood.

Used for blackboard and flooring.

For light carpentry works.

Used for making boxes, cabinet and crates.

For wood frame house.

Bridge construction (parts in contact with water or ground).

# 2.7.7 Canarium schweinfurthii

Common names

(English): African elemi, bush candle tree, gum resin tree, incense tree, purple canary tree

(French): Elemi d'ouganda, elemi de Moahum, elemier d'Afrique

(Luganda): muwafu

(Trade name): African canarium, white mahogany

Botanic description:

*Canarium schweinfurthii* is a large forest tree with its crown reaching to the upper canopy of the forest, with long clean, straight and cylindrical bole exceeding 50m diameter above the

heavy root swellings can be up to 4.5m. Bark thick; on young tree fairly smooth, becoming increasingly scaly and fissured with age. The slash is reddish or light brown with turpentine like odour, exuding a heavy, sticky oleoresin that colours to sulphur yellow and becomes solid. Leaves are pinnate, clustered at the end of the branches, and may be 15-65cm long, with 8-12 pairs of leaflets, mostly opposite, oblong, cordate at base, 5-20cm long and 3-6cm broad, with 12-24 main lateral nerves on each side of the mid-rib, prominent and pubescent beneath. The lower lealets are bigger than the upper ones. The lower part of the petiole is winged on the upper side. The creamy white unisexual flowers about 1cm long grow in inflorescences that stand in the axils of the leaves and may be up to 28cm long. The fruit is a small drupe, bluish-purple, glabrous, 3-4cm long and 1-2cm thick. The calyx is persistent and remains attached to the fruit. The fruit contains a hard spindle-shaped, trigonous stone that eventually splits releasing 3 seeds. Canarium comes from the vernacular name 'kenari' in the Molucca Isles (Mabberley, 1997)

# 2.7.8 Ficus elastica

*Ficus elastica*, also called the rubber fig, rubber bush, rubber tree, rubber plant, or Indian rubber bush is a species of plant in the fig genus, native to Northeast India and sourthern Indonesia. It is a large tree in the banyan group of figs, growing to 30-40 metres (98-130ft) (rarely up to 60 metres/200 feet) tall, with a stout trunk up to 2 metres (6.6ft) diameter. The trunk develops aerial and buttressing roots to anchor it in the soil and help support heavy branches. It has broad shiny oval leaves 10-35 centimetres (3.9-14 in) long and 5.15 centimetres (2.0-5.9 in) broad; leaf size is largest on young plants (occasionally to 45 centimetres/18 inches long). Much smaller on old trees (typically 10 centimetres/3.9 inches long). The leaves develop inside a sheath at the apical meristem, which grows larger as the new lead develops. When it is mature, it unfurls and the sheath drops off the plant. Inside the new leaf, another immature leaf is waiting to develop. In parts of India, people guide the roots of the tree over chasms to eventually form living bridges (Keay *et al.*, 1964).

*Ficus elastic* is grown around the world as an ornamental plant, outside in frost-free climates from the tropical to the Mediterranean and inside in colder climates as a houseplant. Although it is grown in Hawaii, the species of fig wasp required to allow it to spread naturally is not present there.

### 2.7.9 Manilkara obovata:

Family:	Sapotaceae
Genus:	Manilkara
Species:	Manilkara obovata

Manilkara is a very variable species, especially in leaf shape. Some of this variation is correlated with geographical distribution and habitat preference (Keay et al., 1964). Manilkara obovata is widespread in tropical Africa and occupies a wide range of conditions. It is found in evergreen forests on the seashore and at the edges of lagoons. Within the forest zone, it characteristically occurs on the banks of rivers liable to flooding but also in rain forest on welldrained sites. It is a frequent constituent of riparian forest in the savanna regions and also is found in forest outliers and on rocky hills. The tree is about 6 to 30 m high with long, straight cylindrical boles, up to 90 cm in diameter, often fluted at base, but scarcely buttressed. The bark is pale brown with very narrow and deep longitudinal fissures, up to 30 cm long, 6 cm wide and 2.5 cm deep; traverse cracks rather few and shallow; the ridges between the cracks are flat and 1.5 cm to 5 cm wide. The slash is thick hard, chocolate-brown outside, pinkish-red inside, exuding drops of sticky white latex. The leaves of Manikara obovata is up to 16.5 cm long, by 9 cm broad, usually smaller, very variable, obovate to oblanceolate or elongated, rounded, subacute, shortly cuspidate or, rarely emerginate at the apex, usually wedge shaped at the base. The lateral nerves of the leaves is about 20 pairs, indistinct with invisible venation and lower surface with silvery, silky gloss, sparsely to densely covered with fine appressed hairs or sometimes quite glabrous.

#### 2.7.10 Daniellia oliveri

Family:	Fabaceae
Genus:	Daniellia
Species:	Daniellia oliveri

The genus, Daniellia, is named after Dr. Daniell, who visited Siera-Leone and Senegal in the middle of the 19<sup>th</sup> Century (Keay *et al.*, 1964). It is a small tropical African genus which is represented by four species in Nigeria, two of them being common. In Daniellia, the bracteoles are inconspicuous. The individual flowers have stout stalks expanding upwards into a thickened receptacle, with 4 well –developed overlapping sepals and one or three developed petals, the rest being minute. There are 10 prominent stamens free almost to the base, and a flattened ovary on a conspicuous stalk and terminating in a curved style as long as the stamens. The

flowers are borne in ample panicles at the ends of the branchlets. The stapules are conspicuously rolled round the developing shoot and reach several centimeters in length, but fall fairly early. The leaves are large, with 5-12 pairs of opposite leaflets, all much the same size and with fairly long stout stalks, unsymmetrical at the base, thinly leathery and often crowded with translascent dots; the veins and numerous rather irregular thin and vaguely looped lateral nerves form a conspicuous network on both surfaces. The fruits are short flat pods hanging from a slender stalk with the remains of the calyx-tube forming a prominent collar half way up. As a rule only one seed develops, attached by a long slender stalk to one of the valves; if the pod splits open on the tree, seed and valve eventually fall off and spin down looking like a small parachute descending.

# 2.7.11 Lonchocarpus griffonianus.

Family:	Fabaceae/papilionaceae
Genus:	Lonchocarpus
Species:	Lonchocarpus griffonianus

Most of the species comprising the large genus of Lonchocarpus occur in tropical America; three of the four Nigerian representatives are small trees, while the fourth, Lonchocarpus cyanenscens, is a well-known straggling shrub that is the chief source of natural indigo in the South.

*Lonchocarpus griffonianus* is a handsome tree and may be mistaken for Milletia thoningii but is readily distinguished by the conspicuous stiples at the base of the leaflets. The penduluous racemes of showy purplish or lilac flowers are conspicuous and distinctive.

The habitat is forest, particularly on river banks and watersides.

The tree is up to 6-9 m high, sometimes more, with a dense crown; or shrubby and with arching branches drooping at the ends. The bark is grey brownish, thin, fairly smooth, slash yellowish with red streaks. The branchlets are glabrous. The leaves are with a slender glabrous common stalk 7.5-15 cm long; 3-4 pair of leaflets decreasing in size downwards, the terminal leaflets 9.11 cm long by 3.8-5 cm broad, elliptic to slightly oblanceolate, long-acuminate, cuneate, lower leaflets progressing from elongated to ovate and usually rounded at the base; thickly papery, particularly glabrous, with 6-12 pairs of very thin lateral nerves running a wide angle to the midrib, vaguely looped; midrib prominent beneath, base on either small irregular cavities at

the base on either side; leaflet-stalks about 0.6 cm long, with a somewhat shorter, thread-like, persistent stipel at the base.

# 2.7.12 Gmelina arborea:

Family:	Lamiaceae
Genus:	Gmelina
Species:	Gmelina arborea

*Gmelina* is named after J.C. Gmelin, an 18<sup>th</sup> century botanist (Keay *et al.*, 1964). Gmelina is a small tropical Asian and Australian genus composed of trees and shrubs with simple opposite leaves, showy yellow or orange flowers in axillary or terminal racemes sometimes with very conspicuous overlapping bracts, and fleshy drupes containing one or two large stones. One species out of four has been introduced into Nigeria, *Gmelina arborea*.

*Gmelina arborea* is commonly cultivated and readily recognized by its leaves, flowers, and fruits. This is a fast growing tree and likely to be of significance in improving savanna owing to its ability to suppress grasses. The habitat is forest and it is cultivated in plantations. The tree grows up to 21 m high and 2 m in girth, the tole tapering with slight buttresses and smooth tark which is light brown to light grey. The tree is thicky slash, soft, creamy yellow and deciduous. The leaves of *Gmelina arborea* are 15-20 cm long by 10-18 cm broad, ovate, tapering gradually to the apex, almost flat at the base but usually cunneate at the junction with the leaf-stalks; glabrous above, with 2-4 prominent glands at the base, covered with a fine felt of very short hairs beneath. The leaves are strongly 3- nerved from the base and with 3-5 pairs of lateral nerves higher up, almost straight but curving up close to the margin with parallel main veins between; margin entire except in saplings. The stalk is 5-15 cm long.

# 2.7.13 Nauclea latifolia.

Family:	Rubiaceae/Sapotaceae
Genus:	Sarcocephalus/Nauclea
Species:	Nauclea latifolia

The name '*Nauclea*' means little ship in Greek. *Nauclea latifolia* is a small genus of the Old World Tropics. The flowers are in spherical heads with the styles projecting prominently and forming the most conspicuous part of the inflorences, but the fruits of *Nauclea latifolia* are compound, the individual fruits being folded together into a fleshy mass with characteristically pitted surface. The seeds are minute and embedded in a pinkish pulp. *Nauclea latifolia* is a

straggling shrub common in savanna country. The stipules are broadest above the base, elliptic or obovate, very large and conspicuous in young trees. This savanna shrub or scrambling tree has similar stipules with *N. popeguinii*. The wood is darker yellow and softer than the wood of *N.diderrichii*. (Keay *et al.*, 1999).

# 2.7.14 Terminalia superba

Family:	Combretaceae
Genus:	Terminalia
Species:	Terminalia superb

This distinctive tree produces the well-known timber as Afara.

It may be recognized by its broad plank-like buttresses, long straight bole and whorls of think branches often growing practically horizontally. The winged fruits are very distinctive. Terminalia superba is of the habitat, high forest, especially secondary regrowth forest. The tree grows up to 45 m high and 4.5 m in girth, with large thin buttresses and a rather flat crown, occasionally reaching 60 m. The bole is clean and straight, branching right at the top. The bark is greyish, with long shallow fissures, often flaking off in patches, and yellowish slash. The branches are conspicuously whorled and at right angles to the bole in young trees. The leaves are 10-17 cm long and 5-10 cm broad, obovate, rounded towards the apex but terminating in a short acuminate tip, cuneate; rather leathery, glabrous with 6-8 pairs of prominent lateral nerves. The stalk is 2.5-3.75 cm long, sometimes slightly hairy, usually with a pair of prominent glands. The flowers develop between November and January. They are greenish white, about 0.6 cm across; evenly spaced along the central stalk, the whole inflorescence finely hairy and up to 12 cm long; bisexual flowers usually reaching to the end of the central stalk. This species bear fruits in March. The fruits are without stalks, glaborous when ripe, 1.25 to 1.75 cm long and 3.75-5 cm across the stiffly papery wings. The wood is greyish white, turning pale yellowish-brown, often with dark streaks; strong but easily worked.

#### 2.7.15 Mangifera indica.

Family:AnacardiaceaeGenus:MangiferaSpecies:Mangifera indica

*Mangifera* means mango-bearing or mango making in Latin. It is a tropical Asian genus with one widely cultivated species, the Mango. *Mangifera indica* is an evergreen tree with a dense

crown and dark green, rather glossy elongated lanceolate leaves, commonly planted as a shade tree and for its distinctive edible fruits, up to 15 cm long, yellow or reddish when ripe. *Mangifera indica* has a smooth skin, yellowish flesh and large flattened fibrous stone. The flowers are in conspicuous upright terminal panicles and the fruits hang down in clusters. The wood is hard, red, durable and attractive. (Keay *et al.*, 1964).

## 2.7.16 Tectona grandis

Family:	Lamiacea
Genus:	Tectona
Species:	Tectona grandis

The name *Tectona* originates from Tekka, the Malabar name for *Tectona grandis* (Keay *et al.*, 1964). One species of this small tropical Asian genus has been introduced into Nigeria. *Tectona grandis* commonly called teak has very large and broad leaves, shaped rather like tobacco leaves and the large terminal panicles of small white flowers are distinctive. The habitat is rain forest, but widely cultivated in drier areas. The tree is up to 30 m high and 3 m in girth, and deciduous. The bole usually fluted and sometimes with slight buttresses. The bark is grey to brownish fibrous, with shallow longitudinal fissures; slash pale yellow to yellowish. The branchlets are markedly square.

# 2.7.17 Vitex doniana

Family:	Verbenaceae
Genus:	Vitex
Species:	Vitex doniana

The genus of *vitex* is a large one distributed throughout the tropics and subtropics. With rare exceptions the leaves are opposite and digitately compounded. In Nigeria, this combination distinguishes *vitex* from all other genera. Usually there are 3-7 leaflets, the middle ones being the largest.

*Vitex doniana* is the most abundant and widespread *vitex* in savanna regions, readily recognized by its long-stalked glaborous leaves with the leaflets usually rounded at the apex, though sometimes they may be indented or occasionally have a very short triangular tip. The fruits are edible. The habitat of *Vitex doniana* is savanna. The tree is up to 15 m high and 3 m in girth, with a dense rounded crown and dark green foliage. The bark is grey to pale brown, finely fissured longitudinally and fibrous, slash yellowish, darkening on exposure. Twigs and young

foliage quickly entirely glabrous. The leaves are stouty with common stalk 7.5-15 cm long, with 5 obovate to very broadly elliptic leaflets 7.5-15 cm long by 5-8.75 cm broad, mostly rounded at the apex and tapering to the cuneate base; with about 10 pairs of prominent lateral nerves. Leaflets rather leathery and entire. (Keay *et al.*, 1964).

# 2.7.18 Delonix regia

Family:	Fabaceae
Genue:	Delonix
Species:	Delonix regia

*Delonix* is a Greek word for 'clear talon', referring to the conspicuously clawed patels. *Delonix* regia is a handsome ornamental tree known in Nigeria as the 'flamboyant' or 'flame of the forest'. It is a fast growing tree, usually with low, very widely spreading branches producing a flat broad crown. The leaves are about 45 cm long, with very numerous closely crowded opposite leaflets about 1.3 cm long arranged along 11-18 pairs of opposite pineae the whole forming a long-stalked elliptic terminal racemes. They are 8-10 cm across, with long stout stalks, 5 large valvate calyx lobes, bright red within, 5 scarlet petals, the upper one mottled red and white, and 10 free stamens. The fruits are large flat pods up to 60 cm long by 5-8 cm broad, almost black when ripe, hard and woody, hanging conspicuously for a long time on the tree and eventually splitting open. There are numerous elongated seeds about 2.5cm long arranged lengthways across the pods.

## 2.7.19 Newbouldia laevis

Family:	Bignoniaceae
Genus:	Newbouldia
Species:	Newbouldia laevis

*Newbouldia* is named after W. W. Newbould, a 19<sup>th</sup> century British botanist (Keay, *et al.*, 1964). *Newbouldia* is a small genus and is represented in Nigeria by one species, *Newbouldia laevis*. The habitat of this species is secondary forest; often planted. The tree grows up to 18 m high and 60-90 cm in girth. The bole is usually rather irregular and twisted, branching low down. The bark is greyish to pale brown, fairly smooth; slash cream and greyish fibrous, branchlets short and twisted, with short knobbly twigs, the leaves often being clustered at their ends and more or less in whorls. The leaves are up to 50 cm long and usually with 3-5 pairs of leaflets, the common stalk being prominently swollen at the point of attachment of each pair;

leaflets 15.20 cm long by 10.5 cm broad. The leaves are elliptic to broadly elliptic, sometimes, slightly oblanceolate, acuminate, cuneate, rather leathery, dark green, glabrous, usually with coarse teeth but the margin sometimes entire, with 5.20 cm long by 10.5 cm broad. The leaves are elliptic to broadly elliptic, sometimes, slightly oblanceolate, acuminate, cuneate, rather leathery, dark green, glabrous, usually with coarse teeth but the margin sometimes entire, with 5-8 pairs of prominent lateral nerves looped well away from the margin. The leaflet stalk is very short and shout. When it has stayed for long it produces timber.

#### 2.7.20 Dialum guineense.

Family:	Fabaceae
Genus:	Dialum
Species:	Dialum guineense

This is the commonest and most widespread Dialum in Nigeria. The small black velvety fruits are very conspicuous and distinctive. The habitat for this species is forest and forest outliers in savanna country. The tree grows up to 18 m high, but often shrubby, with a densely lead crown. The bole is without buttresses and the bark, smooth, grey slash reddish, yielding a little red gum, sapwood white and with distinct ripple marks. The leaves are with a common stalk 5-12 cm long, sometimes finely hairy, with an odd terminal leaflet and usually 2 pairs of opposite or alternate leaflets, the lower pair being somewhat smaller, leaflets mostly 3.75 – 10cm long by 2.5-5 cm broad. The leaflets are elliptic to broadly elliptic, sometimes slightly obovate, blunt at the apex or abruptly and shortly acuminate, symmetrical and rounded or slightly cuneate at the base; leathery, glabrous above and with the mid rib slightly sunken. They are sometimes finely hairy beneath; with 6-12 pairs of very thin lateral nerves upcurving at a wide angle to the prominent mid rib and looping away from the margin, the veins forming an extremely fine close network. The stalk of leaflets is stoutly, sometimes finely hairy, up to 0.6 cm. (Keay *et al.*, 1964).

## 2.7.21 Azadirachta indica.

Family:	Meliaceae
Genus:	Azadirachta
Species:	Azadirachta indica

The name *Azadirachta* is the Persian vernacular name of this genus (Keay *et al.*, 1964). *Azadirachta* is represented in Nigeria by one species, *Azadirachta indica* which because of its rapid growth and wide range of conditions under which it will grow is of considerable economic importance.

*Azadirachta* is the well-known 'Neem' tree which is one of the most important trees of Eastern India, where it occurs wild and also much planted. It is venerated by the Hindus who use it in religious ceremonies. Because of its dense evergreen crown it is a useful shade tree. Most parts of the plant are used medicinally. The wood is used for house-building and furniture. In Nigeria, it is one of the most widespread introduced tree species and is extensively naturalized. In the drier parts of Northern Nigeria, it is the most successful shade and fuel plantation tree. The tree grows up to 24 m high but usually smaller in Nigeria, with dense, wide spreading crown. The bole is short and stout while the bark is dark brown, rough, with wide shallow longitudinal fissure separated by more or less flat ridges.

# 2.7.22 Anacardium occidentale.

Family:	Anacardieceae
Genus:	Anacardium

Species: Anacardium occidentale

*Anacardium* is a Greek word meaning 'like a heart', referring to the shape of fruit. It is a small tropical American genus with one species widely cultivated in the tropics, the cashew nut tree. Anacardium occidentale is a straggling tree branching very low down, with widely spreading branches that often drop down to the ground. The fruit, a kidney-shaped nut about 2.5 cm long at the apex of a fleshy swollen stalk is highly distinctive. The leaves are 7.5-15 cm long by 5-10 cm broad, obovate, rounded or flat at the apex, cuneate, with a stout stalk and 10-15 pairs of prominent lateral nerves. The flowers are white, small, at first more or less hidden by the conspicuous bracts, borne in lax terminal panicles. The fleshy fruit stalk swells to about 7.5 cm long and 3.75 cm in diameter, becoming rather irregular ribbed, very juicy and yellowish in colour.

# 2.7.23 Hamoa klaineana

Description: Psidium guajava (Botanical). It is a low evergreen tree or shrub 6 to 25 feet high, with wide-spreading branches and square, downy twigs, is a native of tropical America. It is a common vegetation cover by roads and in waste places in Hawaii. Hamoaklain is a tropical and semitropical plant. It is well known in the Islands for its edible fruit. It is common in the backyards. The branches are crooked, bringing opposite leaves. The flowers are white, incurved petals, 2 or 3 in the leaf axils; they are fragrant, with four to six petals and yellow

anthers. The fruit is small, 3 to 6cm long, pear-shaped, reddish-yellow when ripe. In Igbo, it is called gova, gwaabaa in Hausa and Guafa in Yoruba.

# 2.7.24 Ceitus zenkeri

The sweet orange is the Citrus sinensis. It is the most commonly grown tree fruit in the world (Morton, 1987). The ceitis zenkeori is a hybrid of ancient cultivated origin, possibly between pomelo (*Citrus maxima*) and mandarin (*Citrus reticulata*). It is an evergreen flowering tree generally growing to 9 - 10 m in height (although very old speciments have reached 15 m). The leaves are arranged alternately, are ovate in shape with crenulated margins and are 4-10 cm long. (Eol Org). The orange fruit is a hesperidium, a type of berry. It is called Oroma in Igbo, babbaan leemu in Hausa and Osanminu in Yoruba.

#### 2.7.25 Pteracarpus soyauxi

*Pteracarpus soyouxi* is an evergreen tree attaining a height of 18-40 m in the forest but not exceeding 12 m in plantations. It has a relatively short trunk and a deep, dense crown. The bark is pale grey and rough with droplets of resin. The leaves are a compound with 5-8 pairs of leaflets. The upper surface of the leaves is glossy. The flowers are yellow and about 5 mm across. They are arranged in a large inflorescence. The fruit is an ellipsoidal drupe which varies in length from 4 to 12 cm. The skin of the fruit is dark blue or violet, whereas the flesh is pale to light green. The tree flowers at the beginning of the rainy season and bears fruits during 2 to 5 months after flowering. It is called Ube in Igbo and Elemi in Yoruba.

#### 2.7.26 Tetraplura terapera

The oil palms comprise two species of the Arecaceae, or palm family. They are used in commercial agriculture in the production of palm oil. The African Oil Palm, is native to West Africa, occurring between Angola and Gambia, while the American Oil Palm Elaeis oleifera is native to tropical Central America and South America. The generic name is derived from the Greek for oil, elaion, while the species name refers to its country of origin (Collins Guide). Mature trees are single-stemmed, and grow to 20 m tall. The leaves are pinnate, and reach between 3-5 m long. A young tree produces about 30 leaves a year. Established trees over 10 years produce about 20 leaves a year. The flowers are produced in dense clusters; each individual flower is small, with three sepals and three petals. In Igbo it is called Ukwu Nkwu, Kwakwar and Igi-Ope in Yoruba.(Fengel and Wegener 1984).

## 2.7.27 Anogeissue eiocarpus

The coconut palm, Anogeissus eicarpus is a member of the family Arecaceae (palm family). It is the only accepted species in the genus Cocos (Royal Botanic Garden). The term coconut can refer to the entire coconut palm, the seed, or the fruit, which is not a botanical nut. The spelling cocoanut is an old-fashioned form of the word (Pearsall, 1999). Early Spanish explorers called coconuts/cocos nucifera "coco" (meaning "monkey face"). Found across much of the tropics, the coconut is known for its great versatility as seen in the many domestic, commercial, and industrial uses of its different parts. Coconuts are part of the daily diet of many people. Its endosperm is known as the edible "flesh" of the coconut; when dried it is called copra. The oil and milk derived from it are commonly used in cooking and frying; coconut oil is also widely used in soaps and cosmetics. The clear liquid coconut water within is a refreshing drink and can be processes to create alcohol. The husks and leaves can be used as material to make a variety of products for furnishing and decorating. It also has cultural and religious significance in many societies that use it. Cocos nucifera is a large palm, growing up to 30 meters (98 ft) tall, with pinnate leaves 4-6 meters (13-20 ft) long, and pinnae 60-90cm long; old leaves break away cleanly, leaving the trunk smooth. Coconuts are generally classified into two general types: tall and dwarf. On very fertile land a tall coconut palm tree can yield up to 75 fruits per year, but more often yields less than 30 mainly due to poor cultural practices.s In recent years, improvements in cultivation practices and breeding has produced coconut trees that can yield more. (Ravi et al 2009). In Igbo Aki oyibo and Kwaa attaagara.(Gledhill, 1972).

## 2.7.28 Garcina kola

The garcina kola (*Persea americana*) is a tree native to Central Mexico, (Chen *et al.*, 2008) classified in the flowering plant family *Lauraceae* along with cinnamon, camphor and bay laurel. *Garicina kola* or alligator pear also refers to the fruit (botanically a large drupe that contains a large seed) of the tree, which may be pear-shaped, egg-shaped or spherical. *Garicina kolas* are commercially valuable, and are cultivated in tropical and mediteranean climates throughout the world, producing a green-skinned, pear-shaped fruit that ripens after harvesting. Trees are partially self-pollinating and often are propagated through grafting to maintain a predictable quality and quantity of the fruit. In Igbo it is called Ube oyibo and Apoka in Yoruba.

### 2.7.29 Irvingia grandifolio

*Irvingia grandifolio* is a genus of African and Southeast Asian trees in the family Irvingiaceae, sometimes known by the common names wild mango, African mango, or bush mango bear edible mango-like fruits, and are especially valued for their fat- They and protein-rich nuts. The subtly aromatic nuts are typically dried in the sun for preservation, and are sold whole or in powder form. They may be ground to a paste known variously as dika bread or Gabon chocolate. Their high content of mucilage enables them to be used as thickening agents for dishes such as ogbono soup. The nuts may also be pressed for vegetable oil.

The fruit is a large drupe, with fibrous flesh. It is called Ogbono or Ugiri in Igbo, gorono biri in Hausa and Oro abeja.

#### 2.7.30 Khaya Ivorensis

*Khaya ivorensis* is a species of flowering plant in the pea family, Fabaceae, that is native to the tropics and subtropics of the Americas. Its exact origin is unknown due to widespread cultivation (Taxon, 2004). Common names for this species include Pionciana, Peacock Flower, Red Bird of Paradise, Mexican Bird of Paradise, Dwarf Pionciana, Pride of Barbados, and flamboyan-de-jardin. It is called Eko-Omode in Yoruba. Asthma Weed or Cats Hair

Asthma weed is a very common annual herb in Suriname. This hairy plant grows up to 2' in height; it has numerous small flowers clustered together with opposite oblong leaves, which have a toothed margin. The young yellow fruit is a small hairy capsule with 3 reddish-brown wrinkled seeds. There is milky latex in all parts of the plant. The plant flowers and fruits all year long. This tree is called Ogbu in Igbo, Nonan kurchiya in Hausa and Egele, Emi-ile, Yoruba (Keay *et al.*, 1964).

# 2.7.31 Naulea popeguinis

The coral tree has nothing to do with coral reefs-the name comes from the stunning bright red colour of its flowers, which appear on the tree in profusion when it is still without leaves. These flowers stand out starkly against the deeply fissured bark, and present quite a show in the wooded grassland which is its natural habitat. But it is beauty with a sting in its tail-the bark is covered in large, sharp spines. Because of this, the tree is planted for hedging. Only a very determined intruder would try to pass through a hedge made of this tree-and a stupid one, too, because a good coral tree hedge is impenetrable. It is a common tree in villages, planted for its medicinal uses and beauty, as well as for hedging.

A tree growing up to 7 m tall, rarely to 15 m, with deeply fissured, corky bark. The branches and bark are armed with slightly hooked spines up to 10 mm long. The leaves are composed of there regions of the world. It is the largest fruit-tree in the world, capable of a height of one-hundred feet and an leaflets, each measuring  $5-15 \times 4-10$  cm and having a thorny stalk. The flowers appear in large groups at the end of the branches, when the tree is leafless (in the first half of the dry season). The flowers are bright red and 4-5 cm long. The fruit is a bent, twisted and slightly hairy pod,  $7-15 \times 1$  cm. it is constricted between the seeds, which are bright red. In Igbo it is called Echichi, Minjirgaa in Hausa and Ologbosere in Yoruba (Gledhill, 1972).

## 2.7.32 Pyenanthus angolensis

*Phenanthus angolensis* is a fast-growing tree, reaching up to 50 m in height and 2.7 m in girth; bole straight with short buttress; bark grey, smooth at first, becoming scaly with ageing; slash dark red, densely mottled with scattered pits and orange stone-cell granules. Leaves alternate, digitately 3-5 foliate; leaflets sessile or subsessile, glandular, denticulate, often white-felted on the underside at 1<sup>st</sup> with stellate pubescent hairs, becoming glabrous; obovate to obovate-elliptic; apex long-acuminate; base cuneate; stipules large, foliaceus, persistent, deeply toothed. Inflorescence yellow tomentose; male panicles up to 41cm long; female panicles shorter and stouter; male flowers with 5 sepals, a 5-lobed corolla tube and 10 stamens; female flowers with stellate tomentose ovary and 2 styles, slender and bipartite. Fruit indehiscent, 2-3 lobed, 2 celled, with a thick, hard shell and a smell of overripe apples; contains 2-3 red-brown-black seeds, rounded, flat, over 1cm across. Two varieties are recognized: *Pyenanthus angolensis* heudelotii in Ghana, and *Pyenanthus angolensis*. Africanum in Nigeria and westwards. The generic name is based on the Greek words for tick and tree because the seeds were thought to resemble ticks. Normally called Okwe in Igbo, Wamankumi in Hausa and Omodom or erimado (Gledhill, 1972)

# 2.7.33 Hevea brasiliensis

*Acacia nilotica* is a tree 5-20 m high with a dense spheric crown, stems and branches usually dark to black coloured, fissured bark, grey-pinkish slash, exuding a reddish low quality gum. The tree has thin, straight, light, grey spines in axillary pairs, usually in 3 to 12 pairs, 5 to 7.5 cm long in young trees, mature trees commonly without thorns. The leaves are bipinnate, with 3-6 pairs of pinnulae and 10-30 pairs of leaflets each, tomentose, rachis with a gland at the bottom of the last pair of pinnulae. Flowers in globulous heads 1.2-1.5 cm in diameter of a

bright golden-yellow colour, set up either axillary or whorly on peduncles 2-3 cm long located at the end of the branches. Pods are strongly constricted, hairy, white-grey, thick and softly tomentose. Its seeds number approximately 8000 kg. It is called gabaruwa in Hausa and banni in Yoruba and Cacia in Igbo. (Grin, 1997).

## 2.7.34 Nauclea diderrichii

*Nauclea diderrichii* is an evergreen tree that reaches a height of 30-40 m and a diameter of 0.9-1.5 m; bole cylindrical, slender, straight and branchless, rising to 20-30 m and a broad spherical crown with thick foliage. The shining leaves are 15 m long and bigger when young, elliptic, acute at the ends, keeled towards the base, and stipulate, with a pair of distinct leafy stipules at the base. It is mostly deciduous except at the ends of shoots, and the nodes are often occupied by ants. Flowers small, green-white-yellow and tubular, in solitary terminal heads (unbranched), 3cm across; stalks only about 1cm. the fruit is yellow , fleshy, in a globose head deeply pitted between the deeply fused calyx lobes. There are about 250 fruit/kg. it is called Uburu in Igbo, Tafashiya in Hausa and Opepe in Yoruba.

# 2.7.35 Mansonia altissima

*Mansonia altissima* is a species of mango in the Anacardiaceae family. It is found in the wild in India and cultivated varieties have been introduced to other warm average circumference of twelve to fourteen feet, sometimes reaching twenty. The species appears to have been domesticated about 4,000 years ago (Seeley *et al* 1846). The species was brought to East Asia around 400-500 BCE from India; next, in the 15<sup>th</sup> century to the Philippines; and then, in the 16<sup>th</sup> century to Africa and Brazil by the Portuguese (Gepts, 2009). The species was described for science by Linnaeus in 1753 (Grin, 1997).

Mango is the national fruit of India, Philippines and Pakistan. It finds mention in the songs of 4<sup>th</sup> century CE Sanskrit poet, Kalidasa. Prior to it, is believed to have been tasted by Alexander (3<sup>rd</sup> century BCE) and Chinese pilgrim, Hieun Tsang (7<sup>th</sup> centry CE). Later in 16<sup>th</sup> century Mughal Emperor, Akbar planted 100,000 mango trees in Darbhanga, Bihar at a place now known as Lakhi Bagh. It is called Mangoro in Igbo, Mangwaro in Hausa and Mangolo in Yoruba.

### 2.7.36 Garcinia gnetrides

Garcinia gnetrides is a small, North American tree, which grows from approximately 3 - 10metres high. It is common in the temperat wood lands of the Eastern United States. Its small leaves are droopy and gives the plant a tropical appearance. The dark brown, velvety leaves, approximately 5 cm across, grow in sphere-like whorls, and can bloom for up to 6 weeks. Wild Ugoro tree is rough-skinned, dark brown in colour, measuring from 7-14 cm long. It can reach up to 0.30kg in weight extracts of *Garcinia gnetrides* tree has historically been used for herbal treatment of diseases like indigestion, catarrh because it contains alkaloids e.t.c and also the bark of this tree has been used to construct fish nets. The bark, roots and twigs, seeds of this tree contains acetogenins long-chain aliphatic compound with 35-39 carbon atoms ending with a gamma-lactones, cyclised in tetrahydrofuran rings. Acetegenins are known for their cytotoxic, antitumour, immunosuppressive antimalaria, pesticidaly, anti-bacterial and antifeedant properties. The search for newer sources of antibiotics is a global challenge and academia. Since many infections agents are becoming resistant to synthetic drugs. Infectious diseases are the world's major threat to human heath and account for almost 50,000 deaths everyday. Therefore, wood extracts have the major advantage of still being the most effective and cheaper alternative sources of drugs. The local use of natural herbs as primary health remedies is quite common in Asia, Latin America and Africa Garcinia gnetrides L. (botanical name) commonly called Wild Ugoro (English), Abochi Ojii (Igbo-Nigeria). It has been reported that the wood extracts has been used as antihelmints and for the treatment of infections of bacterial origin (Grin, 1997).

### 2.8 WOOD STRUCTURE

Wood is a heterogeneous, hygroscopic cellular and anisotropic material. It is composed of cells and the cell walls are composed of micro-fibrils of cellulose (40 %-50 %) and hemicellulose (15 % - 25 %) impregnated with lignin. In corniferous or softwood species the wood cells are mostly of one kind, tracheids, and as a result the material is much more uniform in structure than that of most hardwoods. There are no vessels (pores) in corniferous wood such as one sees prominently in oak. The structure of hard-wood is more complex, the water conducting capability is mostly taken care of by vessels; in some cases (oak, chesmit) these are quite large and distinct in others (buckeye, poplar) too small to be seen without a hand lens. Therefore there are two ways of discussing such woods:-

- i. Ring porous
- ii. Dttuse porous

In ring porous species such as oak, black locust, catalpa, ash, the larger pores as cross sections of vessels are localized in the part of the growing ring formed in the spring thus forming a region of more or less open and porous tissue. The rest of the ring produced in summer are responsible for smaller vessels and a much greater proportion of wood fibres. These fibres are the elements which give strength and toughness to wood, while the vessels are sources of weakness.

The fibrous nature of wood strongly influences how it is used. Wood is primarily composed of hollow, elongate, spindled-shaped cells that are arranged in grains, parallel to each other along the trunk of a tree. These cells are sometimes referred to as fine cellular ducts in tubes which carry water and dissolved mineral from the roots to the leaves and which are more or less vertically placed within the trunk. When the wood is cut from the tree, lumbers are produced of which the characteristics of the fibrous cells and their arrangement affect such properties as strength, shrinkages and grain pattern of the wood (Regis, 1999).

A cross-section of tree shows the following well defined features (from outside to centre) bark, which may be divided into an outer:



Figure 2.1: The cross section of wood (Dutta, 1981)

**2.8.1 Bark**: Its thickness varies greatly with species and age of trees.

Inner Thin Living Part: It carries food from the leaves to the growing part of tree i.e. the wood.

**2.8.2 Cambium:** This is inside the inner bark and generates new woods and bark cells known as sapwood, it can be seen only with a microscope. In the cambium, cells increase by normal division and eventually differentiate to form bark tissues to the outside of the cambium and wood or xylem tissues to the inside (Core, 1990).

**2.8.3 Heartwood:** This is formed by a gradual change in the sapwood and consists of parenchyma cells that are dead but produce oil, resins, gum, colouring matter, tannins and antiseptic material.

**2.8.4 Sapwood:** This contains both living and dead tissues and carries sap from the roots to the leaves.

**2.8.5 Pith:** This is small core tissue located at the center of tree stems, branches and twigs about which initial wood growth takes place.

## 2.8.6 Heartwood: Sapwood and Cambium

There are different types of wood structures found in a typical trunk of a tree. The wood at the center of the trunk is the heartwood and it is older, darker and more durable than the younger structural elements surrounding it. Heartwood or duramen consists of dead inactive parenchyma cells that do not function in either water conduction or food storage, but before they die, they usually produce oil, resins, gum, colouring matters, tannins and antiseptic material. This saturates the walls of the neighbouring cells. The dark colour of heartwood is usually due to tannin and resin or gum, while it becomes resistant to attacks of bacteria and fungi due to presence of antiseptic oil. (Regis, 1999). As the tree grows, a thin layer of cells called cambium is located at the inner bark and forms wood and bark cells and can be seen only with a microscope. This cambium generates new wood called sapwood. Sapwood is located between the cambium and the heartwood. This is younger wood and sorounds the heartwood. Sapwood is softer and tends to be lighter in colour than heartwood. Sapwood contains living and dead cells and functions primarily in the storage of food; in the outer layer near the cambium, sapwood handles the transport of water or sap. It varies in thickness and number of Growth rings. The sapwood commonly ranges from 4 to 6cm. The transition from sapwood to heartwood is accompanied by an increase in the extractive known as Tylosis i.e. as the sapwood ages natural substances called extractives (tylosis) invades the sapwood and gradually converts it to heartwood. Tylosis makes the wood resistant to fungi and insect attack. All dark coloured heartwood is not resistant to decay and some nearly-coloured heartwood are resistant to decay (Regis, 1999). However, none of the sapwood of any species is resistant to decay. Heartwood extractives may also affect wood by reducing permeability, making the heartwood slower to dry and more difficult to impregnate with chemical preservatives (a) increasing stability in changing moisture conditions, and (b) increasing weight (slightly). However, as sapwood changes to heartwood, no cells are added or taken away, nor do any cells change shape. The basic strength of the wood is essentially not affected by the transition from sapwood cells to heartwood cells (Regis, 1999).

#### 2.8.7 Growth ring

Where there are clear seasons, growth can occur in discrete annual or seasonal forms, leading to growth rings. This can usually be most clearly seen on the end of a log, but are also visible on the other surfaces. If these seasons are annuals these growth rings are referred to as annual rings. Where there is no seasonal difference growth rings are likely to be indistinct or absent. If there are differences within a growth ring, then the part of a growth ring nearest the center of the tree, and formed early in the growing season when growth is rapid is usually composed of wider elements. It is usually lighter in colour than that near the outer portion of the ring and is known as early wood or springwood. The outer portion formed later in the season is then known as the latewood or as summerwood.

## 2.9 Classification of wood

The wood from the many different species of trees is divided into two major categories according to the botanical classification of the trees as seed plants, namely hardwood and softwood (Riegal, 2005). There are two main types of wood-softwood and hard wood. Softwood and hardwood are terms that refer to the water-conducting cells in a living tree from which timber comes and not to the hardness or softness of the wood itself. In softwood, the water-conducting cells are known as xylem tracheids and are tapered in shape, while in hardwoods these cells are tubular-shaped and are known as xylem vessels. Conifers are an example of gymnosperms, or cone-pro ducing plants. All conifer species are softwoods, including radiate pine, an introduced pine species grown in softwood plantations in New South Wales. Angiosperms are flowering plants. Eucalyptus is an example of angiosperms and also a native hardwood species. Balsa wood, although a 'soft' wood is also a hardwood. The names are a bit

misleading, as hardwoods are not necessarily hard, and softwoods are not necessarily soft. The well-known balsa (a hardwood) is actually softer than any commercial softwood. Conversely, some softwoods (e.g yew) are harder than many hardwoods. There is a strong relationship between the properties of wood and the properties of the particular tree that yielded it. For every tree species, there is a range of density for the wood it yields. There is a rough correlation between density of a wood and its strength (mechanical properties) (Riegal, 2005). For example; while mahogany is a medium-dense hardwood which is excellent for fine furniture crafting, balsa is light, making it useful for model building. The densest wood may be black ironwood (Riegal, 2005).

It is common to classify wood as softwood or hardwood, depending on the tree from which they come. Woods from broad-leaved trees are called hardwoods, e.g. Oak wood, and woods from coniferous trees are called softwoods e.g. Pine, regardless of their actual hardness. Thus many softwoods are actually harder than some of the so-called hardwoods. The hardwoods have long, continuous ducts leading through the trunk; the softwoods do not have such ducts, and the fluids are transported from cell to cell. Many types of softwoods have resin ducts running parallel to the grain, and softwoods in general contain considerable resin, whereas few hardwoods have any such material in the wood. Most lumber in the U.S. is softwood; the hardwood is generally employed for furniture and high-grade flooring (B.U.S. Department of Agriculture Madison). When growth rings are prominent, as in most softwoods and ring-porous hardwoods, earlywood differs markedly from latewood in physical properties. Earlywood is lighter in weight, softer, and weaker than latewood. All trees reproduce by producing seeds. Hardwood trees and softwood trees produce vastly different types of seeds. Those for hardwood are always produced with some sort of cover on the seed, while softwood tree seeds will have no covering. The hardwood seeds which are known as Angiosperms can be found in things like apples, pears or acorns. While the seeds for softwoods, are released by the tree without any protection for the seed. The scientific name for softwood trees is Gymnosperms. A more general way to think about the difference is that hardwood trees will lose all of their leaves during cold weather, while the softwood trees will retain their leaves. Trees like the maple or oak are all in the Angiosperm or hardwood family, while trees like the pine or fir trees are part of the softwood or Gymnosperm family. It is also correct to say that Evergreens are in the softwood grouping while deciduous trees are from the hardwood side. Softwoods aren't weaker than hardwoods. Softwoods come from coniferous trees such as cedar, fir and pine and tend to be somewhat yellow or reddish in appearance. Because most coniferous trees grow fast and straight, softwoods are generally less expensive than hardwoods (Riegal, 2005).

# 2.9.1 Softwood

The wood of gymnosperms is commonly referred to as soft and sometimes as non-pored wood. An example of softwood timber is pine, sometimes also referred as whitewood or non-pored wood. The bulk of softwood is made up of long narrow cells that fit closely together. These help to hold the tracherds firmly together. Conifer tracheids can be up to four millimeters long and serve both to transport sap and to strengthen the stem of the tree pits in the cell walls of the tracheids and enables sap to pass from cell to cell as it moves up the stem. Softwood is the source of about 80% of the world's production of timber, with traditional centers of production being the Sattic Region including Scandinavia and Russia and North America (Riegel 2005). Softwood is used as opposed to hardwood, which is the wood from angiosperms trees. Softwood are not necessarily softer than hardwoods. In both groups there is an enormous variation in actual wood hardness, with the range in density in hardwoods completely including that of softwoods. Some hardwood (e.g Balsa) are softer than most softwood. Australia has very few native softwoods, viz; cypress hoop and bunya. Pines are example of native softwoods growing in forests in New South Wales. Softwood plantations of introduced exoted pine have been established in NSN to meet the community's need for softwood timber. (Riegal, 2005).

## 2.9.2 Hardwood

Broad-leaved trees, like eucalyptus and red cedar are hardwood trees. Most Australian native timber trees are hardwoods. The wood of the trees is made up of two distinct types of cells-vessels and fibre cells. Sap is carried upward in large ducts known as vessels or pores. These start as wide cells with large carvities, arranged one above the other. In some cells the end walls break down to create long pipes running considerable distances. Vessels can usually be seen with the naked eye. Timbers with vessels are sometimes called pored timbers (hard and the arrangement of the vessels in a cross-section is a useful for identifying different timbers (Gledhill, 1972). These are similar to conifer tracherds but are short in length (commonly about one millimeter long) and usually thicker walled fibres which make up the bulk of the wood in broad-leaved and like tracherds, the walls of these cells are made up of cellulose and neighbouring cells are held together by lignin. Hardwoods have a more complex structure than
softwood. The dominant feature separating hardwood from softwood is the presence of pores or vessels. The vessel may show considerable variation in size, shape of perforation plates (simple, scalar form, reticulate, foraminate) and structure of cell wall, such as spiral thickenings characteristics. As their name suggest, the wood from these trees is generally harder than softwoods. Hardwoods reproduce broad leaves. Many lose their leaves every autumn and are dominant in the winter.

#### 2.9.3 Wood colour characteristics studies

Wood is chemically composed of macromolecular substances and low molecular weight substances (extractives). The low molecular weight substance include both inorganic and organic compounds which vary among different wood species in quantities that ranged from to 30. The organic compounds are collectively known as extractives as they can be 5% extracted from wood by using the appropriate solvent (Franco and Jon, 2009), and as such they account for the colour and smell of wood and have important applications for coating processes. The extractives can be divided, according to their chemical composition into three main sub-groups, namely, aromatic phenolic compounds, aliphatic compounds and terpenes and terpenoids. Aromatic phenolic compounds are second only to carbohydrates in abundance in wood and include complex polyphenolic molecules. They are principally found in heartwood and responsible for the deeper colour and decay resistance (Franco and Jon, 2009). Phenolic compounds can be sub-divided into four groups which include lignins, stilbenes, flavoniods and tannins. Lignins are stable and colourless in contrast to stibenes which darken in the presence of light. Reactive stilbenes cause staining and drying inhibition of coating on tropical hardwoods. Flavonoids contain a dibenzyl propane unit and are the principal colouring material in trees, plants and flowers. They are mostly found in the heart wood of trees. Another type of reactive polyphenol contains an unusual seven-carbon ring known as a tropolone; thujaplicins are one of the first known examples, they can chelate with iron to give black or blue staining. Thujaplicins are the reason that western red cedar is valued for its durability and dark colour (Franco and Jon, 2009). The major aliphatic compounds in both softwoods and hardwoods are fatty acids and their esters, in particular the triglycerides of saturated and unsaturated acids including linoleic, oleic and linolenic acids. They are important components of alkyd paints. They are volatile, and were once a major paint solvent and used in minor quantities to prevent oil-based paint from skinning prematurely. Extractives are the substances mainly responsible for the wood colour, tannins can r eact with ferrous metal to cause blackening of the heart wood (Franco and Jon, 2009). In consequence of oxidation processes caused by light and oxygen, they are the main agent responsible for the colour change of w ood surface. From literature (http://www.rfs.org.uk/learning /what-wood), wood colour aids the identification of types of wood (hardwood and softwood). Hardwoods come with a variety of colours and shades that often allow immediate and unmistakable recognition. Hardwood colours can range from pure white through red to deep brown or even black while softwoods are paler in colour, ranging from white to yellow, sometimes tinged with colours, although both hardwoods and softwood colours darken when exposed to light.

## 2.9.4 Chemical composition and fiber structure of wood Chemical Composition of Wood

Wood substances are organic materials mainly composed of carbon, hydrogen and oxygen together with small amounts of nitrogen and of mineral element (principally calcium, potassium and magnesium) which are found in the ash when they are completely burnt. Wood is composed principally of three compounds-cellulose, hemicelluloses, and lignin; about 25 percent of hardwood and 30 percent of softwood is lignin (Feirer, 2000).

Cellulose is the common name used for glucan present in wood, which constitute about 42 % of dry weight. Wood cellulose is the primary component of the walls of cells making up fibres and is the main structural material of wood and other plants. Chemically associated with cellulose in the wood structure are other polysacharrides called hemicellulose which often have been labeled as the matrix material of a wood. In hardwood the primary hemicelluloses is a xylem (polymer of xylose) whereas in softwood the primary hemicelluloses is glaucoma although both of these polysaccharide occur to some extent in both types of wood. The degree of polymerization of the hemicelluloses is much less than that of the cellulose in the range of 100-2005. The third major component of wood is lignin. Although lignin also is a polymer, it has a different chemical structure from that of the polysaccharides. The monomeric unit in lignin are phenolic type compounds but the exact chemical structure of lignin is still not known after 100 yrs of intensive research. The spaces between fibre in woods are almost pure lignin and are termed the middle lamella. Lignin is considered the glueing or entrusting substances of wood and add mechanical strength or stiffness to the tree and to the wood. High plants commonly are referred to as lignocelluloses because of the typical joint occurrence in that of lignin and cellulose (Young, and Geese, 1990). In chemical terms, the difference between hard and softwoods is reflected in the composition of the constituent lignin. Hardwood lignin is primarily derived from sinapyl alcohol and coniferyl alcohol. Softwood lignin is mainly derived from coniferyl alcohol (Boerjan *et al.*, 2003).

Aside from the lignocelluloses, wood consists of a variety of low molecular weight organic compounds, such as terpenes, diterpenes, and fatty acids. For example, rosin is exuded by conifers as protection from insects. The extraction of these organic materials from wood provides tall oil, turpentine, and rosin (Fiebach, 2000). Other components of wood include extractives such as tannins, starch, dyes, oil, resin, fat and waxes as well as ash forming materials. These contributes to the wood properties such as colour, odour, taste and resistance to decay. It is also worthy to mention that the chemical composition of wood varies as we go from the bark to the inner layer i.e. the heartwood (Chukwu, 1999).

Generally all wood, irrespective of their botanical genesis has certain common characteristics. They include cellular nature, anisotropy, hygroscopy, biodegradability and inertness to most chemical and so on. Wood is farly stable and has ability to withstand environmental hazards (Pashin, 1980). Aside from water, wood has three main components. Cellulose, a crystalline polymer derived from glucose, constitutes about 41-43%. Next in abundance is hemicellulose, which is around 20% in deciduous trees but near 30% in conifers. It is mainly five-carbon sugars that are linked in an irregular manner, in contrast to the cellulose. Lignin is the third component at around 27% in coniferous wood vs 23% in deciduous trees. Lignin confers the hydrophobic properties reflecting the fact that it is based on aromatic rings. These three components are interwoven, and direct covalent linkages exist between the lignin and the hemicelluloses.







# - alpha(1,3) - Galactose

## Hemicellulose

Source: (Kubler, 2010).

Table 1: Chemical components of some wood species (Riegel 2005).

Constituents	Scotpine	Spruce	Eucalyptus	Silver Barcb
Cellulose (%)	40.0	39.5	45.0	41.0
Hemicellulose (%)	28.5	30.6	19.2	32.4
Lignin (%)	27.7	27.5	31.3	22.0
Total extractive (%)	3.5	2.1	2.8	3.0

Source: Riegel, 2005

TABLE 1.2: AVERAGE CHEMICAL CONTENTS OF WOOD (Riegel 2005)

Elements	Share, % of dry matter weight
Carbon	45-50%
Hydrogen	6.0-6.5%
Oxygen	38-42%
Nitrogen	0.1-0.5%
Sulphur	Max 0.05

Source: Riegel, 2005

Solvent Extractives: This consists of those constituents that are soluble in or organic solvent. The di-chloromethane extractable content of wood is a measure of such substances like: waxes, fats, resins, photo sterols and non-volatile hydrocarbons. The amount of extractive is highly dependent on seasoning or drying of wood. The ethanol-benzene extractive of wood consist of certain other di-chloromethane insoluble components such as; low molecular weight carbohydrates, salts and other water soluble substances. The extractives reduce pulp yield, increases pulping and bleaching chemical consumption and create problems such as foaming during paper-making if not removed. A cursory look at the literature shows that there is only a few published work on chemistry of African timbers, but a voluminous one on temperate timbers. Among these are those of Eboatu and Altine (1991) who studied the thermal characteristics of some tropical wood. Additional work by Eboatu *et al.*, (1994). Determined the fire characteristics of some fire tolerant trees of the Sudan Savanna of Nigeria (Eboatu *et al.*, 1994).

Eboatu and Momoh (1996) have worked on the flammability of tropical woods and investigated on their burning parameters Ekebafe (2009) has reported the methods of improving the flammability of polymeric materials including timbers. Other research activities on African timbers include the joint work of Ajayi *et al.*, (2008) who studied the effect of wood density and bending strength and dimensional movement of flake boards from *Gmelina arborea* and *Leuconna leucocephala*.

#### 2.9.5 Phytochemistry

The subject of wood chemistry or phytochemistry has developed in recent years as a distinct discipline. It is concerned with the enormous variety of organic substance that are elaborated and accumulated by woods and deals with chemical structures of these substances. Phytochemistry in the strict sense of the word is the study of phytochemicals. Many of these are known to provide protection against insect attacks and plant diseases. They also exhibit a number of protective functions for human consumers. (Will, 1960). The medicinal value of wood extracts lies in their chemical substances that produce a definite physiological action on the human body. Therefore, there is a need to evaluate the timbers for nutrient and chemical compositions so as to determine the potential of the indigenous sources of medicine. Nigeria is rich in rare and useful woods from which important drugs could be prepared, which may serve as starting materials for the partial synthesis of some useful drugs (Agbor *et al.*, 2004).The chemical content of a wood qualifies it for use in the pharmaceutical industries. There is a strong relationship between the properties of wood and the properties of the particular tree that yielded it. For every tree species, there is a range of density for the wood it yields. Therefore, it

is a rough correlation between density of a wood and its strength (mechanical properties). For example, mahogany is a medium-dense hardwood which is excellent for fine furniture crafting. Wood in the strict sense is yielded by trees, which increases in diameter by the formation, between the existing wood and the inner bark, of new woody layers which envelop the entire stem, living branches and roots. Wood has been utilized by humans since antiquity. They provided a source of many products required by early humans such as food, medicine, fuel and tools. For example, the bark of the willow trees, when chewed, was used as a painkiller in early Greece and was the precursor of the present – day aspirin. Throughout history different types of wood have served many purposes. The tough, strong, and durable white oak, for example, was a well-proven raw material for ships, bridges, cooperage, barn timbers, farm implements, rail road ties, fence posts, flooring, paneling and other products. In contrast, wood such as black walnut and cherry became primarily cabinets woods. Hickory was manufactured in tough, hard, resilient tool handles. Black walnut was used for barn timbers and tree nails. It is know that wood from trees grown in certain locations was stronger, more durable and more easily worked with tools than wood from the same species grown in other locations.

Modern wood quality research has substantiated that location and growth conditions significantly affect wood properties. In the United States more than 100 kinds of wood are available to the prospective user; but it is very unlikely that all are available in any one locality. About 30 wood types are commonly imported in the form of logs, cants, lumber and veneer for industrial uses, the building trade and crafts. The importance of wood as a raw material supplying fiber, energy, and chemicals is similar in magnitude to its use as a solid material. Lumber, plywood, and reconstituted boards consume about one-half of the timber harvest, usage for fibre, chemicals and fuels accounts for the remaining half. In 1990, over 55 million metric tons of pulp fiber for paper making was derived from the forest. In January 2010, Italian scientists announced that wood could be harnessed to become a bone substitute. But it is likely to take at least five years until this technique will be applied for humans. As scientists and engineers further learn and develop new techniques to extract various components from woods, or alternatively to modify wood, for example by adding components to woods. Further developments include new lignin glue applications, recyclable, food packaging, rubber tire replacement applications, anti-bacterial medical agents, and high strength fabric or composites.

Although the relative value of wood as source of energy and chemicals has varied considerably through decades, wood continues to be an important sources of specialty chemicals and renewable energy and may be even more important in the future (Riegal, 2005). A study by Canadian Wood Council compared the cycle impacts of three homes designed primarily with wood, steel and concrete, over the first 20 years of their life spans. Relative to the wood design, the steel and concrete designs realize more heat or air pollution, produced more solid used more resources, require more energy emitted more green houses gases and discharge more water pollution (Riegel, 2005). When the complete life cycle is considered, including use and disposal, the great majority of the studies indicate that wood products have lower greenhouse gas emission. In the case where wood products cause greater green house gas emission than their non-wood counter parts, the cause was inappropriate post use disposal (Riegel 2005).

Wood structure is complex. The grain orientation is based on location of annular rings and can be defined as end-, edge and face grain. Wood fibers possess capillary properties and a high water-retention capacity. Kampelmacher et al., (1971), pointed out the heterogeneous structures of wood. Conductive tubules (xylem) and fibres are arranged alternatively in more or less dense arrays (annular rings). Typically, moisture conductivity is greatest from an end-grain surface, less from edge grain, and even less from face grain. According to Kampelmacher et al. (1971), a chopping block with fibres perpendicular to the surface (end-grain) can allow for bacterial penetration several centimeters into the wood. In the studies of (Riegal, 2005) low recoveries of bacteria from laboratory contaminated wooden boards brought about questions on whether the disappearance of the bacteria meant their non-viability due to drying out or because of antibacterial properties of wood, or whether the possibility that their inaccessibility once entrapped into the wood structure was due to the sampling technique. Park & Cliver (1996), developed an innovative sampling method that made use of the capillary properties of the fibres to detect bacteria inside the wood. Unfortunately, they did not use this perfusion method to evaluate the viability of bacteria following a normal cleaning procedure, but rather to assess the use of microwave heating to kill the entrapped bacteria, which they succeeded. Abrishami et al. (1994) showed that 88% of the cells inoculated onto dry, new wood adhered to it after 10 minutes. In fact, it was seen by scanning electron microscopy (SEM) that many bacteria were associated with the cytoplasmic regions of dried structural and vegetative elements of the xylem tissue. On the contrary, previously conditioned wood (wet), whether new or used, did not absorb the inoculums very well as the bacterial recovery was high. Moreover, Abrishami et al., (1994). demonstrated by a direct viable count-SEM method that about 75% of the cells adhering to the wood structure (new or used) were viable for up to 2 hours following inoculation. Based on microcosm assay on wood dust/chips and plastic pieces, they concluded these materials to have no beneficial or deleterious effect on the viability of bacterial cells, despite a noticeable reduction (31%) of cells when incubated with wood chips. The antibacterial properties of wood have therefore been questioned. Miller et al. (1996) tested 8 wood species and found that the aqueous ash extract was inhibitory to E. coli 0157:H7. Red oak and cherry extracts had a slight inhibitory activity. However, Riegal, (2005) also reported the inhibitory properties of wood, but concluded that due to extreme washing during the experiments as well as failure to extract an aqueous active compound, these properties were not due to water-soluble compounds. The findings of Galluzzo & Cliver (1996) agreed with those of Riegal (2005) as oak leachates were not bactericidal towards Salmonella enteritidis, in contrast to the oak shavings and chips tested. Even various solvent extractions were conducted on the wood, but the antibacterial effect was not diminished. A similar antibacterial effect was seen with filter paper. Their results therefore indicated that the mechanism of disappearance of Salmonella from oak was rather physical than chemical. In fact, it could be a combination of adhesion and drying effect on the cells. Carried out work on wood with pyrolysis of wood. The energy capacity of dry wood, which include both sensible heat and decomposition heat effect was measured using a differential scanning calorimeter technique. In this work the decomposition heat effect show good correlation with thermo gravimetric data obtained in the study. The work on the rate of heat and smoke characteristic of wood in Ohio State University calorimeter was done by Hao (1988). Here plywood and red oak were tested for heat change and smoke release rate under different sheet flux levels polluted and unpolluted conditions and vertical and horizontal orientation. Heat and smoke release data obtained by the method were reported. The heat release rate by thermal method are constantly lower than that by oxygen. In summary the major product from combustion of wood are CO, CO<sub>2</sub>, and H<sub>2</sub>O while minor or secondary products include methanol from methoxyl group of lignin and acetate acid from acetyl side-chain on hemicelluloses.

#### 2.10 PYROLYSIS

Pyrolysis is the chemical decomposition of condensed organic substances by heating. The word is coined from the Greek-derived elements pyro "fire" and lysys "decomposition". Pyrolysis is a special case of thermolysis related to the chemical process of charring and is most commonly used for organic materials. It occurs spontaneously at high temperatures (e.g. above 300°C for wood and varies for other materials) for example in fibres or when vegetation comes into

contact with lava in volcanic eruptions. In general, it produces gas and liquid products and leaves a solid residue richer in carbon content. Extreme pyrolysis, which leaves mostly carbon as the residue, is called carbonization. It does not involve reactions with oxygen or any other reagents but can take place in their presence (Fang et al., 2006). Pyrolysis is widely applied in the chemical industry, for example, to produce charcoal, activated carbon, methanol and other chemicals from wood, to convert ethylene dichloride into vinyl chloride to make PVC, to produce coke from coal, to convert biomass into syngas, to turn waste into safely disposable substance and for the cracking of medium weight hydrocarbons from oil to produce lighter ones like gasoline. Pyrolysis is an important chemical process in several cooking procedures such as baking, frying, grilling and caramelizing. Pyrolysis is also a tool of chemical analysis, for example, gas chromatography, mass spectrometry and carbon -14 dating. Indeed, many important chemical substances, such as phosphorus and sulphuric acid, were first obtained by this process. It has been assumed to take place during catagenesis, the conversion of buried organic matter to fossil fuels. Pyrolysis is also the basis of pyrography (Evang, 2008). Although water is normally excluded along with other reagents, the term has also been applied to the decomposition of organic material in the presence of superheated water or steam (hydrous pyrolysis) for example in the steam cracking of oil. Pyrolysis is usually the first chemical reaction that occurs in the burning of many solid organic fuels, like wood, cloth, and paper and also of some kinds of plastic. In a wood fire, the visible flames are not due to combustion of the wood itself, but rather of the gases released by its pyrolysis; whereas the flame-less burning of embers is the combustion of the solid residue (charcoal) left behind by it. Thus, the pyrolysis of common materials like wood, plastic and clothing is extremely important for fire safety and fire-fighting. Destructive fires in buildings will often burn with limited oxygen supply, resulting in pyrolysis reactions. Thus, pyrolysis reaction mechanisms and the pyrolysis properties of materials are important in fire protection engineering for passive fire protection. Pyrolytic carbon is also important to fire investigators as a tool for discovering origin and cause of fires. Pyrolysis has been used since ancient times for turning wood into charcoal on an industrial scale. Besides wood, the process can also use saw dust and other wood waste products (Evang 2008). Charcoal is obtained by heating wood until its complete pyrolysis (carbonization), leaving only carbon and inorganic ash. In many parts of the world, charcoal is still produced semi-industrially, by burning a pile of wood that has been mostly covered with mud or bricks. The heat generated by burning part of wood and the volatile byproducts

pyrolyzes the rest of the pile. The limited supply of oxygen prevents the charcoal from burning too.

A more modern alternative is to heat the wood in an airtight metal vessel, which is much less polluting and allows the volatile products to be condensed. The original vascular structures of the wood and the pores created by escaping gases combine to produce a light and porous material. By starting with dense wood-like material, such as nutshells or peach stones, one obtains a form of charcoal with particularly fine pores (and hence a much larger pore surface area), called activated carbon which is used as adsorbent for a wide range of chemical substances. Residues of incomplete organic pyrolysis, e.g. from cooking fires are thought to be the key component of the terra preta soils associate with ancient indigenous communities of the Amazon basin. Terra preta is much sought by local farmers for its superior fertility compared to the natural red soil of the region. Efforts are underway to recreate these soils through biochar, the solid residue of pyrolysis of various materials mostly organic waste. Biochar improves the soil texture and ecology, increasing its ability to retain fertilizers and release them slowly. It naturally contains many of the micronutrients needed by plants such as selenium. It is also safer than other "natural" fertilizers such as manure or sewage since it has been disinfected at high temperature, and since it releases its nutrients at a slow rate, it greatly reduces the risk of water table contamination. Biochar is also being considered for carbon sequestration, with the aim of mitigation of global warming. However, pyrolysis is an endothermic reaction (40) while the burning process is a self-sustaining exothermic reaction (Fange et al., 2006). When a part of any material is exposed to external source of heat, its temperature will rise as a result of heat transfer. As the temperature progressively increases, a point is reached when enough thermal energy has been imbibed as to break bonds. This results in degradation (often called pyrolysis). Pyrolysis may or may not be influenced by oxygen (Carol, 1971). All that is required is heat or high temperature. The pyrolysate or pyrolysis product, whose composition depends on the material, include combustible and non combustible gases as well as carbonaceous char. At optimum oxygen-combustible gases ratio and at right temperature, ignition occurs. Flame is produced and heat is involved. Burning is then sustained by part of the heat of the combustion produced within the flame, some of which is channeled back to the material. The remainder is lost to the surrounding. It has been demonstrated (Miller et al., 1983) that the decomposition or pyrolysis temperature  $(T_{py})$  is dependent upon the effective heating rate. When thermoplasts are progressively heated, there is a temperature at which the originally relatively hard and brittle material will be altered to a viscous or rubbery nature. The temperature at which this important change takes place is the glass transition temperature  $(T_g)$ . as the temperature is further raised beyond  $T_g$ , there comes a stage when the materials melt at the meltinu temperature  $(T_m)$ .

On heating above  $T_m$ , degradation or pyrolysis follows at  $T_d$  or  $T_{py}$ . Non- thermoplastic materials, including thermosets, cellulosic fibres are those that when heated decompose without any intervening observable softening transition. The natural thermosets do not soften at all on heating, i.e. their glass transition temperatures are higher than the temperature of onset of thermal degradation ( $T_d>T_g$ ). Some though strictly classed as thermosets, may soften followed by simultaneous decomposition ( $T_g \le T_d \ge T_m$ ) (Eboatu *et al.*, 1996) Pyrolysis occurs in stages as shown schematically in Figure 2.1



Figure 2.1: Stages of Pyrolysis of a hypothetical Polymer.

Char represents a concentration of the carbon remnants of the pyrolyzed molecule following degradation. In an ideal situation, char formation in materials would be represented by the equation.

$$[C_6H_{10}O_5]n \xrightarrow{\text{Heat}} (6C + 5H_2O)n \dots 2.1$$

In practice however, the above reaction hardly ever happens alone. For example, at high temperature, the material may undergo further decomposition, yielding a combination of other macromolecular species, volatile products as well as gases. The gas or gases evolved from a pyrolysing substance depends, as has been stated earlier, upon the heating rate but more upon the nature of the material. Common among the gaseous pyrolysates are carbon dioxide ( $CO_2$ ), carbon monoxide (CO), ammonia ( $NH_3$ ), methane ( $CH_4$ ), hydrogen cyanide (HCN) and water vapour.

Whenever sufficient quantity of oxygen is available, the pyrolysis products would be rapidly oxidized (react with oxygen). This even will depend on the following factors (Eboatu, 1992). A high enough temperature, for the oxygen/fuel mixture to react. Enough of oxygen is available for the correct fuel ratio and volatile must be flammable or oxidizable. Common oxidizable gaseous pyrolysis products are methane, hydrogen sulphide (H<sub>2</sub>S), ammonia, and carbon monoxide.

The phenomenon can be illustrated by the equation.

Solid polymer 
$$\xrightarrow{T_{nv}}$$
 volatile  $+ \underbrace{O_2}{T_{ox}}$  products  $+ \Delta Hox 2.2$   
(2)

In the above sequence,  $H_{py}$  is the endothermic heat necessary for the pyrolysis of one gram of the polymer at and above  $T_{py}$ . The temperature of oxidation is denoted as  $T_{ox}$  while  $\Delta H_{ox}$  is the exothermic heat of oxidation. From the above scheme, it is obvious that ignition follows if the igniting sources, which may be either radiant heat or piloted flame, raises the temperature of the oxygen-fuel mixture to  $T_{ox}$ . It follows therefore, that where  $T_{ox} \leq T_{py}$ , the result would be spontaneous ignition of pyrolysis products as soon as the correct amount of oxygen is available. It is pertinent to point out, at this juncture that pyrolysis has found many other industrial applications, viz., production of coke, carbon fibre, bio fuel, plastic waste disposal, thermal treatment of refuse, (e.g. sawdust and waste wood, to reduce waste volumes), as well as industrial production of syngas (flammable mixture of carbon monoxide and hydrogen) and bio char (solid char that can either be burned for energy or recycled as a fertilizer). (Fange *et al.*, 2006)

#### 2.10.1 Combustion

Combustion or burning is the sequence of exothermic chemical reactions between a fuel and an oxidant accompanied by the production of heat and conversion of chemical species. The release of heat can result in the production of light in the form of either glowing or a flame [http. 2008 November]. Most fuel of interest are organic compounds (specially hydrocarbon) in the gas, liquid or solid phase.

In a complete combustion reaction, a compound reacts with an oxidizing element, such as oxygen or fluorine, and the products are compounds of each element in the fuel with the oxidizing element. For example:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \qquad 2.3$$

 $CH_2S + 6F_2 \longrightarrow CF_4 + 2HF + SF_6$  2.4

A simpler example can be seen in the combustion of hydrogen and oxygen, which is a commonly used reaction in rocket engines  $\rightarrow$ 

 $2H_2+O_2$   $2H_2O(g) + heat$  2.5

The result is water vapour. In the large majority of industrial applications of combustion and in fires, air is the source of oxygen ( $O_2$ ). In air, each kg of oxygen is mixed with approximately 3.76 kg of nitrogen. The resultant flue gas from the combustion will contain nitrogen:

 $CH_4+2O_2+7.2N_2 \rightarrow CO_2 + 2H_2O + 7.52N_2 + heat 2.6$ 

In reality, combustion processes are never complete. In flue gases from combustion of carbon (as in coal combustion) or carbon compounds (as in combustion of hydrocarbons, wood, etc) both unburned carbon (as soot) and carbon compounds (CO and others) will be present. Also, when air is the oxidant, some nitrogen can be oxidized t various nitrogen oxides ( $NO_x$ ).

Direct combustion by atmospheric oxygen in a flame is a reaction mediated by radical intermediates. The conditions for radical production are naturally produced by thermal runaway, where the heat generated by combustion in necessary to maintain the high temperature for radical production. Combustion can also be defined as a chemical reaction in which heat and light are evolved. Fire or burning require three things to maintain combustion (Sarkar, 2002).

The presence of fuel (any oxidizable material). The presence of oxygen (usually air) and A certain temperature (heat)

Combustion will continue when the above three are present.

Recent research on chemistry of combustion indicates that the contact of oxygen and fuel is not direct but this is in between the oxygen and free radical emitted by the heated fuels at the point of ignition. These free radicals give rise to the visible flames and the evolution of heat. Combustion can be in the form of complete, incomplete, smouldering, rapid, turbulent microgravity and slow (Putnam *et al.*, 1953).

#### 2.10.2 Complete Combustion

In complete combustion, the reactant will burn in oxygen, producing a limited number of products. When a hydrocarbon burns in oxygen, the reaction will only yield carbon dioxide and water. When a hydrocarbon or any fuel burns in air, the combustion products will also include nitrogen. When elements such as carbon, nitrogen, sulphur and iron are burned, they will yield the most common oxides. Carbon will yield carbon dioxide and nitrogen will yield nitrogen

dioxide, Sulphur will yield sulphur dioxide and Iron will yield iron (III) oxide. It should be noted that complete combustion is almost impossible to achieve. In reality, as actual combustion reactions come to equilibrium, a wide variety of major and minor species will be present. For example, the combustion of methane in air will yield, in addition to the major products of carbon dioxide and water, the minor side reaction products, carbon monoxide and nitrogen oxides.

#### 2.10.3 Incomplete Combustion

Incomplete combustion occurs when there is not enough oxygen to allow the fuel (usually a hydrocarbon) to react completely with the oxygen to produce carbon dioxide and water, also when the combustion is quenched by a heat sink such as a solid surface or flame trap. When a hydrocarbon burns in air, the reaction will yield carbon dioxide, water, carbon monoxide, pure carbon (soot or ash) and various other compounds such as nitrogen oxides.

The quality of combustion can be improved by design of combustion devices, such as burners and internal combustion engines. Further improvements are achievable by catalytic afterburning devices (such as catalytic converters) or by the simple partial return of the exhaust gases into the combustion process. Such devices are required by environmental legislation for cars in the most countries, and may be necessary in large combustion devices, such as thermal power plants, to reach legal emission standards. The degree of combustion can be measured and analyzed, with test equipment. Firemen and Engineers use combustion analyzers to test the efficiency of a burner during the combustion process. In addition, the efficiency of an internal combustion engine can be measured in this way, and some states and local municipalities are using combustion analysis to define and rate the efficiency of vehicles on the road today.

## 2.10.4 Smouldering

Smouldering is the slow, low-temperature, flameless form of combustion, sustained by the heat evolved when oxygen directly attacks the surface of a condensed-phased fuel. It is a typically incomplete combustion reaction. Solid materials that can sustain a smouldering reaction include coals, cellulose, wood, cotton, tobacco, peat, duff, humus, synthetic foams, charring polymers including polyurethane foam and organic dust. Common examples of smouldering phenomena are the initiation of residential fires on upholstered furniture by weak heat sources (e.g. a cigarette, a short-circuited wire), and the persistent combustion of biomass behind the flaming front of wildfires.

#### 2.10.5 Rapid Combustion

Rapid combustion is a form of combustion in which large amount of heat and light energy are released, which often result in a fire. This is used in a form of machinery such as internal combustion engines and in thermobaric weapons. Sometimes, a large volume of gas is liberated in combustion besides the production of heat and light. The sudden evolution of large quantities of gas creates excessive pressure that produces a loud noise. Such a combustion is known as explosion. Combustion need not involve oxygen; e.g. hydrogen burns in chlorine to form hydrogen chloride with the liberation of heat and light characteristics of combustion.

## 2.10.6 Turbulent

Combustion resulting in a turbulent flame is the most used for industrial application (e.g. gas turbines, gasoline engines, etc) because the turbulence helps the mixing process between the fuel and oxidizer.

## 2.10.7 Microgravity

Combustion processes behave differently in a microgravity environment than in Earth gravity conditions, due to lack of buoyancy. For example, a candle's flame takes the shape of a sphere (Putnam *et al.*, 1953). Microgravity combustion research contributes to understanding of spacecraft fire safety and diverse aspects of combustion physics.

#### 2.10.8 Flow

Slow combustion is a form of combustion which takes place at low temperatures. Cellular respiration is an example of slow combustion.

## 2.11 PYROLYSIS

For self sustained flame, an obvious requirement is that there must be an excess energy from the combustion stage,  $\Delta H_{ox}$ . This excess heat would cause further pyrolysis of more solids and maintain the high flame temperature necessary for oxidation i.e.

 $\Delta H_{ox} - \Delta H_{py} \rightarrow \Delta H_c$  (heat of combustion) . . . 2.7

Thus, for any combustion process  $\Delta Hc > OJ.g^{-1}$ . The salient features of this discussion are shown in Fig. 2. 2 which is a simplified schematic representation of pyrolysis/oxidation combustion process.



Figure 2.2: Pyrolysis/oxidation scheme of combustion

In practice, pyrolysis and combustion of flammable volatiles occur at the same time. Under ideal conditions, no char is produced. It is also known that piloted flame ignition usually takes place at a lower temperature than non-piloted ignition. In an atmosphere of insufficient oxygen there will be incomplete combustion. The result is essentially carbonanceous products. e.g. char, smoke, unburnt flammable volatiles and non flammable gases.

The smouldering process which usually accompanies combustion proper, presents quite a distinct picture from the gas phase oxidation of volatile pyrolysates. It is a heterogenous oxidation of a solid surface by a gaseous oxidant. The glowing process that occurs in carbonanceous char is usually represented by the equations.

C + 
$$\frac{1}{2}$$
 O<sub>2</sub>   
C+O<sub>2</sub> heat CO<sub>2</sub> $\Delta$ H = -1.31 KJ.mol<sup>-1</sup> 2.8  
CO<sub>2</sub> $\Delta$ H = -4.76 KJ.MOL<sup>-1</sup> 2.9

It is therefore, obvious that the production of  $CO_2$  releases more heat than the evolution of CO. This is so because if there is a means of stopping the reaction at the carbon monoxide stage, then, the combustion will be unlikely self-propagating due to small quantity of heat evolved. A number of factors determine the thermal property of any material. These include the chemical constitution and the environmental conditions such as temperature, pressure, draught or air flow, surface contour ad orientation. The most important single factor is of course the chemical constitution of the material (Reinmschuessel *et al.*, 1973).

#### **COMBUSTION PROPERTIES OF WOOD**

#### 2.11.1 Mechanical Properties

These are the characteristics of a material in response to externally applied forces. They include elastic properties, which characterize resistance to deformation and distortion, and strength properties, which characterize resistance to applied loads. Mechanical properties values are given in terms of stress (force per unit area) and strain (deformation resulting from the applied stressing). The mechanical property values of wood are obtained from samples (without natural defects that would reduce strength, such as knots, checks, splits etc). Mechanical properties values are given in terms of stress (force per unit area) and strain (deformation resulting from the applied stressing). The mechanical property values of wood are obtained from samples (without natural defects that would reduce strength, such as knots, checks, splits etc). Mechanical properties (without natural defects that would reduce strength, such as knots, checks, splits etc). The mechanical properties of wood include elastic, strength, and vibration characteristics. These properties are dependent upon species, grain orientation, and moisture content, loading rate, and size and location natural characteristics such as knots.

## 2.11.2 Physical Properties

These are the quantitative characteristics of wood and its behaviours to external influences other than applied forces. Included here are directional properties, moisture content, specific gravity, thermal conductivity, charring temperature, pH, dimensional stability. Familiarity with physical properties is important because they can significantly influence the performance and strength of wood used in structural applications. (Kubler, 1990).

#### 2.12 properties of wood for combustion analysis

From the study of Bushnell *et al.*, (1989) a systematic compilation of 21 different property values of wood and bark fuel was made to facilitate the engineering analysis and modeling of combustion systems. Physical property values vary greatly and properties such as density, porosity, and internal surface area are related to wood species whereas bulk density, particle size, and shape distribution are related to fuel preparation methods. Density of dry wood and bark varies from 300 to 550 kg m<sup>-3</sup>; bulk density of prepared wood fuel varies from about 160 to 230kg m<sup>-3</sup>. Thermal property values such as specific heat, thermal conductivity, and emissivity vary with moisture content, temperature, and degree of thermal degradation by one order of magnitude. The carbon content of wood varies from about 47 to 53% due to varying

lignin and extractives content. Mineral content of wood is less than 1%, but it can be over 10 times that value in bark. The composition of mineral matter can vary between and within each tree. Fuel properties for combustion analysis of wood can be conveniently grouped into physical, thermal, chemical, and mineral properties. Bark properties should be distinguished from wood properties. Thermal degradation products of wood consist of moisture, volatiles, char and ash. Volatiles are further subdivided into gases and tars. Some properties vary with species, location within the tree, and growth conditions. Other properties depend on the combustion environment. Where the properties are highly variable, the likely range of the property is given. Combustion systems using wood fuel may be generally grouped into fixed bed, suspension burning, and fluidized bed systems. The systems range from residential to commercial and industrial to utility scale. The fuel property data needed depend of course, on the type of application and the detail of the model. In general, combustion models can be classified as macroscopic or microscopic. Wood fuel properties for macroscopic analysis, such as ultimate analysis, heating value, moisture content, particle size, bulk density, and ash fusion temperature, have recently been reviewed (Brown, 1970). Properties for microscopic analysis include thermal, chemical kinetic and mineral data, and these properties have not been collected in one source for wood.

#### **2.12.1 Density**

Physical properties for analysis of combustion systems include density, bulk density, particle size, internal and external surface area per unit volume, porosity, and colour. The density of commercially important wood species in the United States ranges from 300 to 550 kg m<sup>-3</sup> on an oven dry basis. The range in density of bark is similar. Tropical woods vary more widely, with a dry density as high as 1040 kg m<sup>-3</sup>. For a particular species, the variation in dry density is not more than about 10 %. The density of the wood cell wall is 1450 to 1550 kg m<sup>-3</sup> (Weather wax & Tarkow, 1968). With increasing moisture content, both the density and volume increase up to the fiber saturation point of about 30 % moisture. Above this point, only the density increases. Fresh green wood has a moisture content of 35-60 %, on a wet basis. Dried wood used for fuel typically has a moisture content of 5-20 %. The physical properties (other than appearance) are moisture content, Shrinkage, density, permeability, thermal and elastic properties.

#### 2.12.2 Moisture content

Moisture content is a major factor in the processing of wood because it influences all physical and mechanical properties, and durability and performance during use. Normal in-use moisture content of processed wood that has been dried ranges 8-13 %. Moisture content for wood is expressed on either a fractional or percentage basis. Moisture content is defined as the ratio of the mass of water contained in the wood to the mass of the same sample of dry wood. Shrinkage occurs when wood loses moisture below the fibre saturation point. Above that point, wood is dimensionally stable. The amount of the shrinkage depends on its direction relative to grain orientation and the amount of moisture lost below the fibre saturation point. Wood shrinks significantly more in the radial and tangential directions than in the longitudinal direction. The density of wood is determined by the amount of cell wall substance and the volume of voids caused by the cell cavities (lumens) of the fibres. Density can vary widely across a growth or annual ring. The percentage of earlywood and latewood in each growth ring determines the overall density of a wood sample.

#### 2.12.3 Permeability

Permeability is a measure of the flow characteristics of a liquid or gas through wood as a result of the total pressure gradient. Permeability is influenced by the anatomy of the wood cells, the direction of flow (radial, tangential and longitudinal), and the properties of the fluid being measured. Permeability is also affected by the species, by whether the wood is sapwood or heartwood, and by the chemical and physical properties of the fluid.

## 2.12.4 Thermal properties

The primary thermal properties of wood are conductivity, specific heat, and coefficient of thermal expansion. The conductivity of wood is determined by density, moisture content, and direction of conduction. Thermal conductivity in the transverse directions (radial and tangential) is approximately equal. Conductivity in the longitudinal direction is greater than in the transverse directions. For most processing operations, the dominant heating direction is transverse. Thermal conductivity is important to wood processing because heating – whether for drying, curing, pressing, or conditioning – is an integral step. Specific heat of wood is dependent on moisture content and, to less extent, on temperature. (Harris *et al.*, 1985)

#### 2.12.5 Electrical properties

Dry wood is an excellent insulator. By measuring wood's electrical resistance, electrical moisture meters accurately determine the moisture content of wood in the 5-25% range. Two other electrical properties of interest are the dielectric constant and the dielectric power factor for alternating current, grain orientation, and temperature. The power factor is a measure of the stored energy that is converted to heat.

#### 2.12.6 Elasticity

Elasticity: Wood is both an elastic and plastic material. Elasticity manifests itself during loading and at moisture contents and temperatures that occur in most service uses of wood. The elastic stiffness or modulus of elasticity of wood is dependent on grain orientation, moisture content, species, temperature, and rate of loading. The stiffness of wood in the longitudinal (fibre) direction is utilized in the manufacture of composite products such as oriented strand board, in which the grain or fibre direction is controlled.

## 2.12.7 Strength

Strength: The strength of wood, like its elastic properties, is dependent upon rate of loading, species, moisture content, orientation, temperature, size and location of natural characteristics such as knots, and specimen size. The strength of individual wood fibres in the longitudinal direction can be significantly greater than that of larger samples with their complex anatomy and many defects. As with stiffness, the excellent strength characteristics of wood in the direction of the fibre can be maximized during the manufacture of wood composites by controlling fibre alignment.

## 2.12.8 Vibration

Vibration: Damping and sound velocity are two primary vibration phenomena of interest in structural applications. Damping occurs when internal friction dissipates mechanical energy as heat. The velocity of a sound wave through wood can be used to estimate mechanical stiffness and strength: the higher the velocity, the higher the stiffness and strength. Like other properties of wood, the velocity of sound along the three principal axes differs. Sound velocity in the longitudinal direction is two to four greater than in the transverse directions. (Haris, *et al.*, 1985).

#### 2.13 Preprocessing and pretreatment of wood for energy production

Preprocessing and pretreatment procedures may be undertaken to make wood more suitable for energy uses, and include physical and chemical processes to change wood characteristics (e.g., bulk density, particle size, moisture content, chemical structure). Physical preprocessing technologies such as drying, pelletizing/briquetting, and charcoal production are more typically used in thermal applications although they could also be used in biochemical applications. However, pretreatment technologies are critical for biochemical conversion processes.

#### 2.13.1 PREPROCESSING TECHNOLOGIES

#### 2.13.1.1 Drying Wood

Wood energy processes, particularly thermo chemical processes, require consistent, low moisture materials.Dry wood contains more energy per pound than moister wood and increases combustion efficiency. Consistent moisture is needed to optimize the combustion process and minimize emissions resulting from incomplete combustion. Long term storage of moist materials may result in mold formation, rotting, or other deterioration of the material. Wood piles can be dried by circulating air through the pile to prevent internal heat and condensation. Similarly, fresh air can be circulated through wood stored in bins and silos. These types of operations are typically time intensive and require large spaces to supply commercial operations, and are less commonly used than other methods. Direct heating methods dry the wood using flue gases from combustion processes. It is an efficient process for operations where the flue gas can be directed to the dryer, and some of the dried material fed to the combustion unit, creating a self-contained system. Rotary drum dryers are commonly used as they can operate at high temperatures and quickly dry woody materials. Direct heat drying systems produce volatile organic compounds during combustion, necessitating emission cleaning systems, such as thermal oxidizers. Rotary drum dryers also increase the ash content of pelletized materials due to the fly ash in flue gas becoming attached to the material and subsequently being included in the finished pellets. Indirect heating is more commonly used to dry wood for pelletization or other processes where the material is not directly fired, and uses hot water or steam. Belt conveyor, tube bundle, or fluid bed criers are most commonly used. Belt conveyor dryers typically use heated air to dry material but can use direct heating sources as well. They operate at low temperatures and usually do not have emissions (Wagenfuhr and Steiger, 1992). Related issues. However, drying time can be much longer than for other dryers. Tube bundle dryers are less common. They also operate at low temperature which reduces emissions, but increases drying time. Fluid bed drying is a promising new technology, more commonly used in Europe, but North American manufacturers are also developing these systems. In a fluid bed dryer, the wood flows through the system on a cushion of air forced from below through a perforated metal plate. This bed of air surrounds the wood particles and permits their movement, maximizing drying efficiency. Fluid bed dryers have short drying times, low emissions, and are efficient. However, bridging (interlocking of wood particles that stop material flow) can occur with larger sized wood particles. Drying research and development activities focus on maximizing system efficiency (i.e., reducing time and energy use, increasing volume flow), reducing capital and operational costs, and reducing emissions. (Franco and Jon, 2009).

#### 2.13.1.2 Pelletization/Briquetting

Pelletizing arose as a means to handle wood waste materials such as sawdust. Though commonly used their fine particle size and low bulk density cause handling problems and provides significantly less energy per unit volume. The pellet process compresses the material into higher bulk density units, typically  $\frac{1}{4}$  inch to  $\frac{5}{16}$  inches in diameter for home heating, but larger sizes can also be made. Briquetting processes use a similar compression process as pelleting, but produce larger sized finished products. Pellets and briquettes are easy to handle and energy dense, and are increasingly being used to supply materials for heat and electricity. Manufacturers are also using larger sized wood particles (e.g., waste blocks from hardwood flooring) to create pellets and briquettes. The wood pelleting process is simple, and similar to that used for agricultural feed pellets. For pelletization to be effective, the wood must be at a consistent moisture level (10-12%). Insufficient moisture causes overheating and charring of the pellet, while excess moisture creates pellets that don't hold their form and more readily break apart. Most pellet operations that consume green wood, dry the wood using rotary drum dryers. Following drying and if needed, the wood is reduced in size using a hammer mill. The screen size used depends on pellet size and type being produced (i.e., smaller pellets require smaller die openings and smaller particle sizes). Particle sizes are typically less than <sup>1</sup>/<sub>4</sub> inch. Following the drying and hammer mill operations, the woody material passes through a conditioning unit which sits directly on top of the pelletizer. Here steam is added to moisten the wood surface (to aid binding and solid pellet formation), and chemical binding and/or lubricating agents are added to increase pellet durability. The material next moves to the pelletizer which uses rollers to force the woody material through holes or a flat die. The pellet dies is often thick (greater than 1 <sup>3</sup>/<sub>4</sub> inches) and the holes tapered to increase the pressure on the wood and raise its temperature. Hole diameter and taper significantly affect pellet durability and quality, and the pellet will not bind if the temperature is too high or too low, mounted knives knock the pellets loose from the outside of the die, permitting cooling, usually with a counter flow cooler. The cooling process "sets" and hardens the pellet and reduces fines developed during handling. Wood briquetting is similar, but simpler, than pelletizing. The dried woody material is pushed through a narrow opening which pressures the material to form large pieces that can be cut to size. Briquetting pressure and temperature are lower than for pelletization.

A screw extrusion system is typically used to push the woody material through the opening, although some systems use hydraulic pistons. Pelletization and briquetting are relatively common in Europe, and are becoming more prevalent in North America. Currently, 110 wood pelletization facilities have been identified in the United states and Canada in Canada, wood pellet production in 2008 was 2 million tonnes of which 250,000 tonnes were used in the country, 450,000 tonnes were exported to the US, and 1.3 million tonnes were exported to Europe and other parts of the world (Franco and Jon, 2009). US pellet production was 1.8 million tonnes in 2008, with 80% of production being in the country and only 20% exported. Wood pellets are produced primarily for home use or small-scale heat production. Home heating pellets typically must meet several standards including:

Density-pellets must have consistent hardness and energy content, and weigh at least 40 pounds/cubic foot. Dimension – pellets must not exceed 1  $\frac{1}{2}$  inches in length and be  $\frac{1}{4}$  to  $\frac{5}{16}$  inches in diameter to ensure predictable fuel quantities and prevent jamming.

Fine – pellets must limit the amount of material derived from fine materials (material capable of passing through 1/8 inches screen) to no more than 0.5 percent by weight. This limits dust resulting from breakage during handling and problems with pellet flow during operation.

Chlorides – Pellets must not exceed 300 parts per million of salt to avoid stove and vent rusting.

Net calorific value of 18.5 GJ/t.

Pellets are available in premium and standard grades, which differ by ash content premium pellets contain less than 1% ash while standard pellets contain up to 3% ash by weight. Research and development efforts focus on durability, ash content, and the use of binding agents. Europe is the primary market for North American home heating pellets and briquettes. Pellets must be durable to withstand extensive handling and prevent deterioration of pellet

quality encountered during export and shipping activities. Binding agents (e.g., black liquor, lignin byproducts, glycerol, etc.) increase durability but may increase certain organic and inorganic compounds that can cause emission problems. In Canada and the U.S., pellets compete with heating oil, electricity, and other heat energy sources which are low cost relative to European fossil fuel prices. Lower production costs are needed to increase use in North America (Franco and Jon, 2009).

#### 2.13.1.3 Charcoal Production

Charcoal is a widely used in the metallurgic, purification, and cooking industries, and has been produced for millennia. Charcoal is the carbon based byproduct that results when woody materials are heated to high temperatures under conditions of no or low oxygen (pyrolysis). To make charcoal, wood is heated to high temperatures (above 275°C), which releases water and volatile organic compounds. The wood begins to carbonize at this point. The process is exothermic and increases temperatures to the point that chemical reactions cease and charcoal is formed (over 350°C). At this point, heat can be used to remove tar from the charcoal. The charcoal is then cooled and processed into briquettes or other forms for easier handling. Briquettes are formed by crushing the charcoal into a fine dust and adding a binder (typically starch or sawdust in 70-30 mixture) to hold the briquette together. The mixture is passed through a press to form the briquette and then dried (< 5% moisture) for home or industrial uses. Traditional charcoal production uses either batch or continuous kilns. Continuous kilns are most common and average 2.75 tons of charcoal per hour using automated systems. Average charcoal yields of up to 20% per weight of biomass used can be achieved. Cyclone technologies are used to control particulate matter emissions, while gaseous emissions are reduced by afterburning (up to 80% reduction in VOCs and carbon monoxide). Batch kilns are used in smaller operations and produce less charcoal and take longer than continuous kilns. Modern facilities use a retort system to produce charcoal. In this system, the pyrolysis vapours (volatile organic compounds) are separated from the residual material early in the heating process. Originally developed to allow production of chemicals (e.g., acetic acid and methanol) from the separated vapours, the vapours are now used to produce the electricity and/or heat used throughout the production process. Use of the vapours also reduces emissions in addition to providing energy. Retort systems achieve higher charcoal yields (20-30%) compared to traditional techniques. Opportunities to simplify retort technologies, thus reducing capital costs, exist. Yield improvements and production at larger scales can also reduce production costs.

Combining charcoal and energy production through the use of vapors or though co-locating charcoal facilities with other biomass-to-energy facilities permits joint use of equipment, and could potentially reduce costs (Franco and Jon, 2009).

#### 2.13.1.4 Pretreatment Technologies

Pretreatment is a critical element of biochemical processes as it prepares the woody material for efficient conversion to fuels or chemicals, and determines the yield, and reactivity of the resulting process streams Lignocellulosic biomass is a complex mixture of cellulose, hemicelluloses and lignin. The primary goal of pretreatment is to remove lignin and other extractive compounds which inhibit further digestion or fermentation of the materials. Pre-treating biomass increases hydrolysis sugar yields to nearly 90% of theoretical yields compared with less than 20% without pretreatment. Not all pretreatments work equally well for all biomass materials. In general, woody biomass is more difficult to pretreat than agricultural materials, and certain processes (e.g., acid, organosoly, and acid mediated steam explosion) are more effective for wood than agricultural residues. Ineffective pretreatment is primarily responsible for low enzymatic conversion rates in softwood. Several reviews describe the many pretreatment processes available for biomass (Franco and Jon, 2009).

#### 2.13.1.5 Steam Explosion

Eberboard production (i.e. hardboard or Masonite) have long used steam explosion to pretreat wood for energy uses, the steam pretreatment removes hemicelluloses, making the cellulose more accessible to hydrolysis enzymes, and thus easier to extract and convert. In the steam explosion process, biomass is heated to high temperatures under high pressure conditions for a pre-defined time, causing acids contained in the biomass to hydrolyze the hemicelluloses to sugars, making them more accessible for further enzymatic hydrolysis. Steam is preferred as the heat method as it can rapidly heat the biomass while not diluting the hydrolyzed sugars. To conclude the process, the pressure and temperature are rapidly reduced, causing the biomass to fracture and become smaller in size. The change in biomass structure aids subsequent enzymatic digestion of cellulose, but does not significantly improve conversion efficiency. The remaining hemicelluloses and other extractive materials one be removed prior to any additional hydrolysis. Steam explosion, though effective, generates low sugar yields. Recent efforts that focus on adding a catalyst or chemicals (e.g., soaking in sulfur dioxide) prior to explosion to enhance cellulose accessibility have shown promise. Steam explosion is commercially used in

the biofuels industry. Other similar pretreatments (e.g., hydrothermolysis which uses water in addition to steam) are being explored, but are still in the lab or pilot stage. A liquid hot water pretreatment process appears promising due to its relatively low costs, limited need for size reduction, and use of no caustic agents (Evang, 2008).

#### 2.13.1.6 Chemical pretreatments

Chemical pretreatment focuses on cellular deconstruction, increasing access to cellulose by breaking the bonds between it and lignin, and increasing the surface area of material being processed to aid in enzyme access. Pretreatment of wood utilizing the addition of chemicals is a common technique to improve the release of sugars and other extractives from the plant material specifically for liquid biofuel production. Dilute Acid - Dilute acid pretreatment combines acids (e.g., nitric, sulfuric, hydrochloric) with water. Sulfuric acid has been most widely studied as it is inexpensive and highly effective. Dilute acid pretreatment is often conducted in conjunction with a steam explosion process. The impregnation of the woody material with an acid prior to steam applications significantly increases the release of sugar compared with steam explosion only. Acids are corrosive and require the use of steel tanks and pipes which increases capital investment costs. Byproducts such as salt, may also be produced and require disposal or subsequent processing. Ammonia - based pretreatments have been studied extensively. Several different techniques, including supercritical ammonia, ammonia soaking, and ammonia fibre/freeze explosion (AFEX) have been utilized. The AFEX treatment is most promising as it produces near theoretical yields of celluloses at lower enzyme load levels. The process passes ammonia through the biomass in high temperature reactors where it reacts with lignin and separates it from the cellulose. The ammonia is recovered and recycled, further lowering costs. Removing lignin at the end of the process significantly increases the ability to hydrolyze biomass at even lower enzyme loadings, decreasing the overall process cost even more. This process produces significant delignification of woody biomass. Alkaline – The use of high pH chemicals, such as sodium hydroxide and lime (calcium hydroxide) to pretreat biomass has been shown to be relatively effective for agricultural residues but have not shown as much promise for woody biomass. Similar to other chemical pretreatments, alkaline chemicals combined with a steam explosion treatment show greater releases of hemicelluloses and lignin. Solvent - The organosolv (solvent) process uses organic solvents (e.g., methanol, ethanol, acetone) to delignify the biomass and release hemicelluloses. The process has been developed and more thoroughly studied for wood pulping applications than bioenergy production. Organic solvents are expensive and the resulting materials are complex and more difficult to process. Other - Other chemical pretreatment techniques include sulfur dioxide, carbon dioxide, and a host of other chemicals. AFEX, and the liquid hot water pretreatments have received the greatest focus and are the most promising prospects for commercialization. Dilute acid pretreatment has much higher rates of cellulose conversion than steam explosion pretreatment, but also has higher costs and risks associated with its corrosive nature and the production of residues during the process. AFEX and liquid hot water treatments produce high cellulose conversion efficiencies but have not been as widely applied or studies as the other two processes. Several barriers to commercializing pretreatment technologies exist. Many have been developed and tested only at a lab scale or pilot scale. Scaling the technology to commercial size will require significant engineering of reactors and other vessels. Processes that produce a residue or byproduct will require plans to dispose of, or use, potentially large volumes of material. Systems that combine physical and chemical preprocessing and pretreatment technologies need to be evaluated. And a better understanding of the mechanisms (at a molecular scale) by which pretreatment functions is needed to direct research to improve efficiency and lower cost.(Franco and Jon, 2009).

#### 2.14 effects of some chemicals on wood

#### 2.14.1 Effects of heavy metals on wood

Mercury, arsenic, and lead are found naturally in the earth, but just because they are natural chemical elements does not mean they are harmless. They are heavy metals with a long history of industrial and personal use – and just as long as history of harming human health. When mercury gets into water or land, bacteria convert it to toxic methylmercury, which builds up and are absorbed by trees. When we eat fruits or make use of these woods for house hold utensils without proper treatment, it tags along and settles in our bodies.

Until 2002, arsenic compounds were used to treat wood to prevent rot. The arsenic leaches out into soil and rubs off the wood on to people or animals. Also, woods containing adequate amount of arsenic are used to make drugs.

Woods containing lead, when used for constructions at water sources, leaches out into water resulting to lead exposure if in a toxic amount.

#### 2.14.2 Effects of iodine in wood

Iodine (as iodide) is widely but unevenly distributed in the earth's environment. Most iodide is found in the oceans ( $\approx$ 50 µg/L), and iodide ions in seawater are oxidized to elemental iodine, which volatilizes into the atmosphere and is returned to the soil by rain, completing the cycle. However, iodine cycling in many regions is slow and incomplete, and soils and ground water become deficient in iodine. Crops grown in these soils will be low in iodine, and humans and animals consuming food grown in these soils become iodine deficient. In plant foods grown in deficient soils, iodine concentration may be as low as 10 µg/kg dry weight, compared to  $\approx$ 1 mg/kg in plants from iodine-sufficient soil. Trees grown iodine deficient soil results to retarded growth of the tree.

## 2.14.3 Effect of moisture content on wood

Wood is a natural, fibrous material, and it gains and/or loses moisture as changes occur in the temperature and humidity of the surrounding air. For example, lumber located in a cool humid climate would tend to have a higher moisture content than if the climate was warm and dry. This ability of wood to absorb or desorbs moisture is important in wood design since moisture content affects the structural properties of wood (Gerhards, 1982).

Basic Properties Affected by Moisture Content include: weight, dimension and strength.

Moisture content for a given sample of wood is defined as the weight of water in wood expressed as a percentage of the weight of wood fibrous material (which is considered to be the oven dry weight of the sample).

#### 2.14.4 Saponins in Wood

Saponins are natural detergents found in many plants. Saponins have detergent or surfactant properties because they contain both water-soluble and fat-soluble components. They consist of a fat-soluble nucleus, having either a steroid or triterpenoid structure, with one or more side chains of water soluble carbohydrates. Certain desert plants are especially rich in saponin content. The two major commercial sources of saponins are Yucca schidigera, which grows in the arid Mexican desert, and Quillaja saponaria, a tree that grows in arid areas of Chile. Thus, the surfactant activity is a result of both fat-soluble and water-soluble moieties in the same molecule. There are several current and potential applications of yucca and Quillaja products in animal nutrition. Yucca extract is used as a feed additive to reduce ammonia and fecal odors in animal excreta. Saponins, by virtue of their surfactant properties, have antiprotozoal activity

Saponins has membranolytic properties; they complex with cholesterol in protozoal cell membranes, causing cell lysis. They have antibacterial activity and modify ruminal fermentation by suppressing ruminal protozoa and selectively inhibiting some bacteria. Ruminal ammonia concentrations are reduced. Yucca extract is used for prevention and treatment of arthritis in horses, although convincing evidence of its efficacy has not been reported (Schorger, 1926).

#### 2.14.5 Effects of peroxides on wood

It is well known that in the presence of concentrated  $H_2O_2$  and alkali wood undergoes vigorous decomposition at ordinary temperatures. At comparatively low concentrations, however,  $H_2O_2$  has a bleaching action on wood which has found some application commercially. The mechanism of this bleaching action is little understood, and (Schorger 1926) has stated that the light colour obtained is seldom permanent. who apparently first studied the action, obtained, in presence of NH<sub>3</sub>, satisfactory results with freshly felled maple, lime, aspen and white poplar woods. He observed that during the bleaching process the system rapidly became acidic. Griiss (1923) observed microscopically that after warming with concentrated  $H_2O_2$  and subsequent drying the tracheids of pine wood became encrusted with crystalline material. Further, the treated tissue failed to give the so-called lignin colour reaction with phloroglucinol.

#### 2.15 Atomic absorption spectroscopy

This has become one of the most improved techniques on the quantitive determination of metals. It has gained favour with analyses because, it is specific and sensitive. The sample under examinat ion is digested or ashed to remove organic malter. The remaining mineral matter is dissolved and the resultant solution is aspirated into the flame of the instrument. The metals hollow cathode lamp is fitted and the requisite beam of light is passed through the popula tion of the a tom. For example, it lead hollow cathode lamp is fixed, only lead atoms will absorb the light emitted by it. Part of the energy will be absorbed by the specific atoms, which absorb at that wavelength e.g. 283.3 nm for lead.

The absorption is compared to that obtained when standard solutions of the metal in question are aspira ted so as to determine the concentration. This is done by preparing a series of standard solutions of known concentrations and successively aspira ting them into the burner. The absorbeness are then obtained, the absorbance values are plotted against concentration. As with other spectroscropic technighes, the Beer-lambert's law is obeyed in that absorbance is proportional to the concentration of atoms in the flame and hence to the concentration of the element in the aspi ra ted solution. If a linear calibration curve results, the slope of the calibration curve can be obtained and use made of the equation nA = MC where A is Absorbance and C is concentration to calculate the concentration of the unknown solution. It is however, important to remember that at high absorbance levels, the relationship between absorbance and concentration may depart from linearity. Additions should be of approximately the same concentration as that anticipated for the dilute sample solution. Important instrumental features of a modern a tomic absorption instrument include the following facilities:

- 1. It should have a lamp turnet capable of holding at least four hollow cathode lamps with an independent current stabilized supply of each lamp.
- 2. There should be the incorporation of an auto sampler which can work with both flame and furnace atomizers. Improved analytical precision is obtained when an auto sampler is used in conjunction with a furnace atomer.
- 3. The monochromator should be capable of high resolution, typically 0.04nm. This feature is most desirable if the AAS is adapted for flame emission work; good resolution is also desirable for many elements in atomic absorption.
- The photomultiplier should be able to function over a wide wavelength range from 188 800 nm. (Okoye, 2005).
- 5. All instruments should be equipped with a background correction facility. Virtually all instruments now have a deuterium arc background correction. The Zeeman system is also available in instruments marketed by the Perkin-Elmer incorporation and smith-Hieftje system by Thermo Electron limited.
- 6. The use of an integral video screen in instruments presents very great advantages, both in the case of operation and in the ability to develop and understand analytical methods. Complete analytical methods records can be s tored in the instrument and a visual display of good calibration curves can be stored in memory and recalled at will. It is most useful to have a graphical display of atomization peaks when using a furnace where distinction can be made of the total absorbance peak and that due to the analyte absorbance.

## **CHAPTER THREE**

## MATERIALS AND METHODS

## **3.1 Sample collection and Identification**

Fufty (50) tree samples were collected randomly from eleven states in Nigeria namely Abia, Anambra, Ebonyi, Enugu, Imo, Edo, Oyo, Kwara, Ekiti, Ogun and Benue. Each tree samples was recognized and identified by the forest officer, timber dealer who assisted in collecting the leaves of such trees. This was taken to the Botany Department of this University for identification according to their scientific names by Professor Izundu.

#### Methods

#### **3.1.1** Sample collection and preparation.

The tree species were recognized and identified by the forest officer, timber dealers and literature according to their vernacular and scientific names. From each of these states, some tree species were felled. Each felled tree was cross cut into three sections from base to top, that is bottom, middle and top giving a total of one hundred and fifty test samples. The wood samples were ground into fine powder that passed through 0.5 mm mesh using the Angle grinder or polisher by Siemens Germany. The powdered wood samples were oven dried and and kept in air tight polyethene bags ready for analysis.

#### **3.2 Methodology**

Qualitative phyto-chemical analysis were carried out using the methods of (Harborne, 1998),to ascertain the presence of the different phytochemicals in the wood samples before the quantitative analysis was carried out.

## Materials

## List of Eqiuptment used Are:

- 1. Soxhlet extractor
- 2. Glass funnel
- 3. Condenser apparatus
- 4. Electronic weighing balance, Model B218.
- 5. Desicator
- 6. Distillation apparatus

- 7. Hj-3D constant temperature magnetic stirrer by B.Bran Scientific and Instrument Company England
- 8. Conical flask
- 9. Haier Thermocool Refrigerator
- 10. Centrifuge Model 80-2 by Healtrh Medical Equipment, England.
- 11. Microlit High Precision pipette, capacity 100-1000ml
- 12. Seperating funnel
- 13. Sayona Electric Oven (181 capacity)
- 14. Electrical  $p^{H}$  meter,  $p^{H}$  S-25 by life care
- 15. Spectrum Lab 23A, (spectrophotometer) by life care
- 16. Flat bottom flask
- 17. Boiling water bath
- 18. Combustion tube
- 19. Litmus paper (red and blue)
- 20. Test tube
- 21. Boiling tube
- 22. Measuring cylinder
- 23. Beaker (250ml)
- 24. Gas jar
- 25. Heating mantel
- 26. Whatman filter paper, No 42 (125mm)
- 27. Gem filter paper (12.5cm)
- 28. Universal indicator paper 1-14 Q/GHSC 1544-1999 made by Shanghai SSS Reagent Co. Ltd
- 29. Stiring glass rod
- 30. Crucible (china dish)
- 31. Volumetric flask
- 32. Ignition tube
- 33. Rubber cork
- 34. Specific gravity bottle
- 35. Thermometer  $(0-360^{\circ}C)$
- 36. Angle grinder/ polisher by Siemens Germany

## List of Reagent uesd are:

- 1. Hydrochloric acid
- 2. Phosphomolybdic acid
- 3. Folin Denis reagent
- 4. Olive oil
- 5. Sulphuric acid
- 6. Ethyl acetate
- 7. N-butanol
- 8. Petroleum ether
- 9. Disodium ethylenediamine tetra acetate
- 10. Ammonium hydroxide
- 11. Methyl orange indicator
- 12. Potassuim permanganate (KMnO<sub>4</sub>)
- 13. Ferric chloride
- 14. Distilled water
- 15. Methanol
- 16. Sodium lauryl sulphate
- 17. Sodium hydroxide
- 18. 2-ethoxy ethanol
- 19. Sodium carbonate
- 20. Acetic anhydride
- 21. Diethyl ether
- 22. Calcium chloride
- 23. Sodium borate decahydrate
- 24. Ethanol
- 25. Phenolphthalin indicator
- 26. Disodium hydrogen phosphate
- 27. Glacial acetic acid
- 28. Sodium chloride
- 29. Chloroform
- 30. Buffer solution
- 31. Orthophosphoric acid
- 32. Acetic/nitric reagent

- 33. Ice block
- 34. Fehlings solution
- 35. Dragennorff's reagent
- 36. Standard glucose stock
- 37. Molish reagent
- 38. Mayers reagent
- 39. Boric acid
- 40. Sodium sulphate
- 41. Copper sulphate
- 42. Mollon's reagent
- 43. Aluminium chloride
- 44. Anthrone reagent

## Methods

## 3.2.1 Test for Saponins

20 ml of distilled water was added to 2 g of the wood powder in 100 ml beaker for each of the samples, and boiled gently on a hot water bath for 15 minutes. The mixture was filtered allowed to cool, and the filtrate used for the following test:

**3.2.2 Frothing Test:** Exactly 10 mi of each filtrate was diluted with 5 ml of distilled water and shaken vigorously. A stable froth (foam) upon standing indicated the presence of saponins. Emulsion: To the frothing solution was added 2 drops of olive oil and the content shaken vigorously. The formation of emulsion indicated the presence of saponins (Harbone, 1998).

## 3.2.3 Test for Flavonoids

30 ml of ethyl acetate were added to about 2 g of the powdered wood material, and was heated on water bath for 10 minutes. The mixture was cooled, filtered, and the filtrate was used for the following tests:

**3.2.4 Ammonium Test:** exactly 10 ml of the extract was shaken with 3ml of dilute ammonium solution. The layers were allowed to separate and presence of yellow coiour in the ammonical layer indicated the presence of flavonoid no yellow colour in the ammonical layer indicated the absence of flavonoids.

#### 3.2.5 Test for Resins

**Precipitation test.** Exactly two grams of the powdered materials was extracted with 50ml of 90% ethanol. The alcoholic extract was then poured into 30ml of distilled water in a beaker. A precipitate occurred which indicated the presence of resins.

**3.2.6 Colour test:** Exactly 2g of the powdered wood was extracted with chloroform and the extract was concentrated to dryness. The residue was re-dissolved in 5ml acetone and 5ml conc HCl added. This mixture was heated in a water bath for 30minutes. A pink colour which changes to magenta red indicated the presence of resins (Hikino *et al.*, 1984).

#### **3.2.7** Test for protein

Millions Test: 50mls of distilled water was added to 2g of each wood sample and left for 4hours and then filtered. To a little portion of the filtrate in a test-tube, two drops of Millions reagent was added. A white precipitate indicated the presence of protein.

## **3.2.8** Test for extracted oils from the timber samples.

Two grams of each wood sample was extracted with 30 ml of 90 % alcohol and filtrated. To the filtrate was added 3 ml of 5 % ferric chloride solution. Presence of a green colour showed the presence of oils.

#### 3.2.9 Test for cardiac glycosides

5ml of 50 % v/v ethanol and 10 ml of 15 % lead acetate solution were added to 2 g of the powered wood sample in a 100 ml conical flask. The flask was boiled in a water bath for 5minutes, cooled and filtered twice with 15 ml chloroform. One (1ml) of the extract was added to 50 %  $H_2SO_4$  and was heated in boiling  $H_2O$  for 5 minutes. 10 cm<sup>3</sup> of Fehling solution (5 cm<sup>3</sup> of each solution A and B) was added and boiled. A brick red precipitate indicated the presence of glycosides.

## **3.2.10** Test for tannins

Two grams of the powdered wood sample was boiled with 50 ml of distilled water for 5 minutes and was cooled and filtered and was used for the following test:

**3.2.11 Ferric chlorides test:** To 3ml of the filtrate two drops of ferric chloride solution was added. Presence of greenish black precipitate showed the presence of tannins.

## **3.2.12** Test for alkaloids

50ml of 5 % sulphuric acid in 50 % ethanol was added to about 2 g of the powdered wood material and heated on a boiling water bath for 10minutes, cooled and filtered. 3ml of the filtrate was tested with a few drops of Meyer's Reagent (Mercuric Chloride and Potasium iodided) A cream colour o precipitate indicated the presence of alkaloids.

#### **3.2.13** Test for carbohydrates

About 2 g of the powdered wood samples were boiled with 10 ml of distilled water in a test tube and filtered. Few drops of Molisch's reagent were added to the filterate in the test tube and 5ml of concentrated  $H_2SO_4$  was then gently poured down the side of these tubes to form a lower layer. Formation of a ring with a purple colour at the outer surface indicated the presence of carbohydrate.

## 3.2.14 Test for acidic compounds

Some ten grams of wood was placed in clear dry test-tube and sufficient distilled water was added. This was warmed in a hot water bath and then cooled and filtered. A piece of water-wetted red and blue litmus papers was dipped into the filtrate and colour change on the litmus paper was observed to be red, showing the presences of acid (Amadi *et al.*, 2004).

# 3.3 QUANTITATIVE DETERMINATIONS OF PHYTOCHEMICALS IN WOOD SAMPLES

## 3.3.1 Saponin Determination

Twenty grams of each of the powdered samples were defatted with 200 ml of 20 % ethanol. The suspension was heated over a hot water bath for four hours with continuous stirring at about 55°C. The mixture was filtered and the residue re-extracted with another 200 ml of 20 % ethanol. The combined extracts were reduced to 40 ml over water bath at 90°C. The concentrate was transferred into a 250 ml sepa rating funnel and 20 ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered while the organic layer was discarded. The purification process was repeated. 60 ml of n-butanol was added. The solution was washed twice with 10ml of 5 % aqueous sodium chloride. The remaining solution was heated in a water
bath. After evaporation, the compound (saponin) was dried in the oven to a constant weight and thereafter weighed (Obadoni and Ochuko, 2001).

#### **3.3.2 Flavonoids Determination**

10 grams of each of the powdered sample were extracted repeatedly with 100 ml of 80 % aqueous methanol at room temperature. The whole solution was filtered through Whatman filter paper No. 42. The filtrate was later transferred into a crucible and evaporated to dryness over a water bath, and thereafter weighed (Boham and Kocipal, 1994).

Calculation

% flavonoids = (weight of crucible residue) -(weight of crucible) x 
$$\frac{100}{1}$$
 3.2

## **3.3.3** Determination of Resins

The boiling tube was filled with 2.00g of the powdered wood sample. The tube was clamped and heated for 10mins without the gas jar to drive away the air in the apparatus before connecting the gas jar. The wood sample in the boiling tube was heated for 2 hours in the absence of air. Simple substances obtained are: wood charcoal, pyroligeneous gas, wood tar and wood gas. The content was filtered and the liquid substance (Resin) obtained, measured and weighed to determine its actual weight present in each wood.

Calculation

% Resin = 
$$\frac{\text{wt of resin}}{\text{wt of wt sample}}$$
 x  $\frac{100}{1}$  3.3

#### **3.3.4 Protein estimation** (Modified Kjeldahl's Method):

1ml of the sample extract was measured into a kjeldahl flash, 30 ml of concentrated  $H_2SO_4$  was added into the digestion flask and heat was applied in the fume cupboard using hot plate. The heating continued until the solution turned green. Then extra 1 hour heating took place followed by cooling overnight.

The digested sample in the kjeldahl flask was transferred to 500 ml conical flask followed by the addition of 200 ml deioniscd water. 70 ml of 40 % NaOH was added and distillation column was connected (apparatus set up) using 250 ml conical flask containing 50 ml of 4 %

boric acid indicator, Then the distillation continued till 150 ml distillate was collected; the subsequent distillate was checked by dropping it on the pH paper to check the presence of Ammonia gas. Then the distillation was stopped immediately, there was no colour change on the

pH paper. The titration was carried out using 0.1M HC1 to a pink end point and the reading was taken immediately.

Calculation =

% protein =  $\frac{\text{Titre value x } 0.0014 \text{ x } 6.25 \text{ x } 100}{\text{Weight of sample extract used}}$ 3.4

# 3.3.5 Extraction and determination of the percentage Oil

Method: soxhlet extraction method was used to extract the oil from the wood

Apparatus: extraction thimble, round bottom flask, 500 cm<sup>3</sup> reflux condenser, heating mantle, analytical weighing balance, Spatula, beaker, retort stand, filter paper.

**Reagent:** Petroleum ether (b.p 60-80°C)

**Procedure**: The soxhelt extractor was set up and approximately 10 g of the dried powdered sample was weighed out accurately using the metler balance and then put into the extraction thimble of known weight ( $W_1$ ). Its weight with the sample was taken ( $W_2$ ). The thimble with the sample was placed inside the soxhlet extractor which was fitted into the neck of a 500 ml capacity round bottom flask containing chips which prevented bumping or trotting due to pressure. Reasonable quantity of petroleum ether was poured into the extractor to wet the sample wrapped in the thimble. In addition, considerable quantity of petroleum ether was poured into the round bottom flask. The soxhlet extractor with the thimble and condenser was fixed into the round bottom flask which had already been fitted in a heating mantle. The heating was maintained at a temperature range of 60-80°C for 14-15 hours after which the flask was disconnected and the thimble was removed and the ether was reclaimed by connecting a receiver apparatus.

#### 3.3.6 Oil recovery

The remaining (solvent) ether was removed by distilling over a water bath and the remaining ether was left to dry off at  $105^{\circ}$ C for about 30 minutes. The percentage by mass of the oil in the sample was respectively calculated from the difference in weighing (W<sub>3</sub>)

## **3.3.7** Determination of cardiac glycoside

Approximately two grams of each powdered wood sample was weighed into a 250 ml round bottom flask and 200 ml of distilled water was added and allowed to stand for 2hours. The content was then filtered and the filterate collected. To 5ml of extract was added 1ml of 2 % solution of 3, 5 -DNS (Dinitrosalicylic acid) in methanol and 1ml of 5% aqueous NaOH. It was boiled for 2 minutes until brick-red precipitate was observed and the boiled sample was filtered. The weight of the filter paper (whatman No: 42) was weighed before filteration. The filter paper with the absorbed residue was dried in an oven at 50°C till dryness and weight of the filter paper with residue was noted. The cardiac glycoside was calculated thus.

Calculation

% cardiac glycoside = 
$$\frac{\text{weight of filter paper} + \text{residue} - \text{weight of filter paper}}{\text{Weight of sample}} = \frac{100}{1} 3.7$$

# 3.3.8 Tannin determination

To five grams of the powdered sample in a conical flask was added 100 mls of petroleum ether and covered for 24 hours. The sample was then filtered and allowed to stand for 15 rmnutes allowing petroleum ether to evaporate. It was then re-extracted by soaking in 100 ml of 10 % acetic acid in ethanol for 4hrs. The sample was then filtered and the filterate collected. 25ml of NH<sub>4</sub>OH were added to the filterate to precipitate the alkaloids. The alkaloids were heated with electric hot plate to remove some of the NaOH still in solution. The remaining volume was measured to be 33 ml; 5rnl of this was taken and 20 ml of ethanol was added to it. It was titrated with O.IM NaOH using phenolphthalein indicator until a pink end point. Tannin content was then calculated in % (C<sub>1</sub>V<sub>1</sub> = C<sub>2</sub>V<sub>2</sub>) molarity.

Calculation:

$\mathbf{C}_1$	=	Cone. of Tannic Acid
$\mathbf{C}_2$	=	Conc. of Base
$V_1$	=	Volume of Tannic acid
$V_2$	=	'Volume of base

Therefore $C_1 = C_2 V_2$				
$\overline{V_1}$				
% of tannic acid content =	$\mathbf{C}_1$	X	<u>100</u>	
	wt, of sample		1	3.8

#### 3.3.9 Alkaloids determination

Two grams of each of the samples were defatted with 100ml of diethyl ether using a soxhlet apparatus for 2 hrs. approximately 500 mg of each of the deffated samples, was weighed into 250 ml beaker and 200 ml of 20 % acetic acid in ethanol was added and covered to stand for 4 hrs\ This was filtered and the extract concentrated to one-quarter of the original volume using water-bath. Concentrated ammonium hydroxide was added dropwise to the extract until precipitation was complete. The whole solution was allowed to settle and precipitate collected and weighed (Harborne, 1973., Obadoni and Ochuko, 2001).

Calculation:

% Alkaloid = 
$$\frac{\text{weight of Alkaloid}}{\text{Weight of sample}} \times \frac{100}{1}$$
 3.9

#### **3.3.10** Determination of total carbohydrate

Anthrone reagent was prepared by dissolving 200 mg of anthrone in I00 cm<sup>3</sup> of ice-cold, 95 % tetraoxosulphate (VI) acid. The standa rd glucose stock was prepared by dissolving 100mg of standard glucose in 100 ml of distilled water. The working standard solution was prepared by dissolving 10 ml of the standard glucose stock in 100ml of distilled water, followed by the addition of three drops of toluene. One gram of each wood powdered was weighed into a boiling tube and hydrolysed by keeping it in a boiling water bath for 3 hrs with 5 cm<sup>3</sup> of 2.5 M hydrochloric acid. It was cooled to a room temperature and neutralized with solid sodium carbonate until effervescence ceased. The content was made up to 100 ml by volume and centrifuged. The supernatant was collected and 1cm<sup>3</sup> of distilled water was added to 1cml of the aliquot (supernatant solution) followed by the addition of 4 ml of anthrone reagent. The mixture was heated for 8 minutes in a boiling water bath, cooled and optical density measured at 630nm. The carbohydrate standard curve was prepared by pipetting (0-1 ml) of the working standard solution into six different test tubes where "0" serves as a blank. 1 ml of distilled water for

8 minutes. After eight minutes, it was cooled and optical density measured at 630 nm. (Hedge and Hofreiter, 1962). From the graph the amount of carbohydrate present was calculated as

Carbohydrate (mg/g) = 
$$\frac{\text{mg of glucose}}{\text{Vol. of test sample}} = \frac{x \ 100}{\text{I}}$$
 3.10

Each determination was carried out three times

# **3.4 PHYSICAL PROPERTIES OF FIFTY** (50) **TROPICAL WOOD SAMPLES Determination of moisture content**

2.00 g of each wood sample was weighed into a pre-heated, cooled and weighed crucible. The wood sample in each crucible was dried in an oven for 24 hours at a regulated temperature of 100  $^{\circ}$ C to a constant weight. Each crucible and its content after drying was cooled in a dessicator and then weighed (Amadi *et al.*, 2004).

The moisture content was determined as the percentage moisture given by

% moisture = <u>weight of wet sample-weight of oven dry wood sample</u>	Х	100	
Weight of oven dry wood sample		1	3.11

#### **3.4.1** Determination of ash content

Five grams of each sawdust wood sample was weighed into a known weight of crucible  $(W_1)$ . The sample in the crucible was ashed in an electric furnace at 450°C for three hours. After ashing, the crucible and its content was left overnight to cool. After cooling the crucible with its content was reweighed  $(W_2)$ , The ash content was determined as percentage ash thus:

% Ash = 
$$\frac{W_2-W_1}{wt \text{ of sample}}$$
 x  $\frac{100}{1}$  3.12  
or  
% Ash = weight of crucible plus ash - weight of crucible x  $\frac{100}{1}$  3.13

#### 3.4.2 Determination of Specific gravity of wod

Specific gravity (SG) is the density of a substance relative to the density of water and is sometimes known as relative density or basic density. Ten grams of the wood sample was tied with a weightless thread and inserted into a basin full of water. Some water whose volume was measured was displaced. The volume of the displaced water was equal to the volume of the sample. Density of the wood was calculated as:

Density = 
$$\frac{\text{Mass of sample}}{\text{Volume of water displaced}}$$
 3.13

By weighing the water displaced, the density of the water was also calculated

Density = 
$$\frac{\text{Mass of water displaced}}{\text{Volume of water displaced.}}$$
 3.14

Therefore the specific gravity of wood was calculated as

# 3.4.3 Determination of crude fibre

5.00 g of each dry wood sample was weighed into a thimble and transferred into the soxhlet extractor chamber fitted with a condenser and a flat bottomed flask. 150 mls of petroleum ether enough to cause reflux was poured into the flask. The sample was extracted of its lipid and interfering pigment for 3 hours at a temperature of 60  $^{\circ}$ C. After extraction, the sample was dried in oven for 3 hours at a temperature of 80  $^{\circ}$ C

After drying, 2.00 g of each wood sample was boiled with 200 ml tetraoxosuphate (vi) acid for 30 minutes on an electric hot plate with antibumping chips and filtered through muslin cloth and washed with boiling water until the wood sample was no longer acidic. The residue was boiled with 200 ml of 0.5 M sodium hydroxide solution on an electric hot plate for 30 minutes and filtered through muslin cloth and washed with 25 ml of boiled 1.25 % tetraoxosulphate (vi) acid, 350 mI of water and 25 ml of ethanol. The residue was removed and transfered to an ashing dish (preweighed dish  $W_1$ ) and dried for 2 hour at a temperature of 130 °C. The dish was cooled in a dessicator and weighed ( $W_2$ ). The ashing dish with the residue was placed in a muffle furnace for 30 minutes at a temperature of 600 °C, the dish was cooled in a desiccator and reweighed ( $W_3$ ) (Maynard, 1970). The crude fibre content was determined as follows: (Amadi *et al.*, 2004 and TAPPI, 1983).

% crude fibre = loss in weight on ignition 
$$(W_2 - W_1) - (W_3 - W_1)$$
 x 100  
Weight of sample 1 3.16

### **3.4.4** Determination of fibre length

The wood chips were made soft by soaking in a solution of 10 % ethanoic acid and 50 ml hydrogen peroxide for 5 hours to bleach the chips. Distilled water was used to rinse off the acid solution, while shaking in a test-tube to separate the fibres. The fibres were placed in a

microscope slide, and viewed using a zeiss electronic microscope with an ocular micrometer guage fitted in. The fibre length was determined using the formula below: TAPP1, USA (Tappi 212-M-54)

Fibre length (L)s = Length (mm) x conversion factor (6.00) 3.17

#### 3.4.5 Determination of thermal or heat conductivity of timbers by the ash method

Each clean crucible was weighed and 2.0 gram of each of the ground samples were taken in the weighed crucible. The samples were burnt on an electric plate for four hours, allowed to cool at room temperature and then reweighed. The weight of the ash was obtained by subtracting the weight of the empty crucible from the weight of the crucible and ash. The result obtained was divided by 2 gram to get the actual fraction of the ash in the weighed sample.

Weight of ash =Wt of crucible + ash-Wt of crucible  
Fraction of the ash = 
$$\frac{Wt \text{ of crucible + ash - Wt of crucible (g)}}{2 \text{ g}}$$
 3.18

If fraction of the ash is multiplied by 100, percentage ash content is obtained.

By comparing the fraction of the ash obtained with the conversion Table, the Conductance Ash Table for low conductivity cells," the thermal conductivity of the timber sample was obtained (See Appendix).

#### **3.4.6** Determination of the charring temperature

Some 0.50 g of the wood sample was placed inside an ignition tube into which a thermometer  $(0-360 \ ^{\circ}C)$  was inserted. The combustion tube was then clamped on a heating mantle. As the material was heated to char point, the exact char temperature was recorded and respective results were obtained.

#### **3.4.7** Determination of pH

The hydrogen ion concentration of the wood sample was determined using electrical pH meter PHS-25 made by Life Care. Some 50 cm<sup>3</sup> of distilled water was added to 0.50 g of each wood sample weighed into a 250 ml beaker. The mixture was allowed to stand for 72 hours. The pH meter was standardized by dipping its glass electrode into buffer solutions of pH4 and pH8 in turn. This was followed by rinsing the glass electrode with distilled water and drying of the glass electrode with clean cotton wool. The pH measurement was done by dipping the glass

electrode into the slurry mixture of each wood sample and the pH reading was taken (Amadi *et al.*, 2004 and TAPPI, 1983).

# 3.4.8 Determination of porosity index

1.00 g of cold water starch was prepared with 5 ml of water. The starch which serves as an adhesive was mixed with 1.03 g of the wood powder. The mixture (slurry) was moulded into ring shape and allowed to dry on exposure to air for 15 hours. The moulded dry wood sample was weighed using an electronic weighing balance. Model B218 and dried weight was determined. The dried wood sample was soaked in 75 ml paraffin oil for 24 hours. The soaked dried wood sample was weighed and the weight noted (Amadi *et al.*, 2004 and TAPP1, 1983).

#### **3.4.9 Determination of fiber saturation point**

The wood species were cut to sizeable samples of 100 mm x 60 mm x 40 mm for the purpose of

Oven drying to constant weight, afterwards, each specimen was extracted from the seasoned samples by cutting to a standard dimension of 30 mm x 20 mm x 20 mm.

Thereafter, the test species were completely immersed in water for 30 minutes. Subsequently at regular intervals of 15 minutes, their moisture contents were measured with the moisture meter until an initial (green) moisture content of at least 30 % was attained for each test piece. This is the fiber saturation point (FSP) of wood at which shrinkage begins to occur (Stamm, 1927).

# **3.4.10 Determination of colour**

The colours of the wood sample were determined using physical method. The colours of the wood samples were matched with chemistry colour chart and respective colours were obtained (Amadi *et al.*, 2004 and TAPPI, 1 983).

# 3.5 DETERMINATION OF SOLUBILITIES OF THE WOOD SAMPLES

The solubility of the fifty tropical timbers in 1 % NaOH solution, cold, hot water and ether were determined according to TAPPI standard (T212-M-54). 5 g of each sample was added in 50 ml of each of the following: NaOH solution, ether, cold (25  $^{\circ}$ C) and hot (100  $^{\circ}$ C) water respectively. The mixtures of sodium hydroxide, hot water and ether were allowed to stand for

an hour, but six hours for cold water mixture, while stirring at same time interval. The mixture were later filtered, the residue rinsed with water, oven dried at 105 °C, cooled in a desiccator and weighed. The solubilites were calculated using the formular (Amado *et al.*, 2004 and TAPPI, 1983).

Solubility = loss in weight/volume of water x 1001 3.20 **3.6 CHEMICAL CHARACTERIZATION OF OIL** 

**3.6.1 Acid value determination** (ASTM: American Society for Testing Material (1985), Van Nostrand, 1976).

**Procedure**: One gram of the oil was weighed accurately into a conical flask and was dissolved with 15 ml of chloroform. Two drops of phenolphtalein indicator was added to the flask and the solution was titrated against 0.05 M alcoholic potassium hydroxide. The colour at the end point was pink. The number of mg of potassium hydroxide required to neutralize 1g of oil was then calculated as;

Acid value = 
$$\frac{\text{Volume of KOH x Molairty of KOH x Molar mass of KOH}}{\text{g of oil}}$$
 3.21

### 3.6.2 Free fatty acid value determination

Free fatty acid is the half of the acid value.

Free fatty acid value = <u>Acid value</u>

## **3.6.3** Saponification value determination.

**Procedure:** One gram of the oil was weighed accurately into a round bottom flask after which exactly 50 ml of alcoholic potassium hydroxide (KOH) and few pieces of boiling chips were added to the weighed sample. Two drops of Phenolphthalein indicator was added to the sample. The round bottom flask was fitted to a reflux condenser and this was left to boil for 30 minutes so as to clear the solution. The solution was titrated against 1M hydrochloric acid in order to get the number of ml of caustic potassium hydroxide consumed by the fat during saponiflcation. The saponification value was thus calculated from the formula below:

Saponification =  $(c-b) \times M \times Molar \text{ mass of KOH}$ 

			a
Where a	= we	ight of	the test sample in g
	b	=	ml of HCl used in titration
	c	=	Ml of KOH added to sample
	m	=	molarity of HCl

# 3.6.4 Determination of peroxide value

One gram of the extract sample was measured into a boiling tube. 20 ml of glacial acetic acid and chloroform in the ratio of 2:1 was added. The mixture was boiled for 1min, in a water bath. Then it was poured into a flask containing solution of 20 ml (5 %) KI. The boiling tube was washed twice with 25 ml of distilled water and was also poured into the flask. It was titrated using 0.002 M Na<sub>2</sub>S<sub>2</sub>O<sub>7</sub> and starch solution as an indicator (about 0.5 ml). It was titrated until the colour changes to colourless.

Formula of peroxide value - 
$$1000 \times V_1 \times M$$
  
Weight of the extract 3.24

OR

$$P.V. = \frac{2 \times V}{W}$$
3.25

# 3.6.5 Determination of Iodine Value (Wij's Method):

0.5 ml or 1 g of the sample was measured into a conical flask, and 15ml of chloroform was added, followed by the addition of 25 ml of Wij's solution, (iodine monochloaide). It was covered tightly with a foil and was placed in the dark for 30 mins. 20mls of 10 % KI solution was added followed by the addition of 150 ml of distilled water. The colour changes to red. Now, the red coloured solution was titrated with 0.1 M Na<sub>2</sub>S<sub>2</sub>O<sub>7</sub> until reddish colour separates from the solution.5 ml of 1 % starch indicator was added and the colour changed to blue black and the solution was titrated until the colour changes to pale black end point.

Calculations: (c-b) x m x molarity of thio sulphate consumed x molar mass of iodine

3.26

3.23

where a = mass of test sample

c = Ml of added Iodine monochloride

a

b = Ml of thiosulphate consumed

m = molarity of thiosulphate consumed.

# 3.7 Determination of polymeric component of wood

# 3.7.1 Determination of cellulose

2.00 g of each wood sample was weighed and transferred into a 250 ml Eryfemeyer flask. 50 ml of 96 % ethyl alcohol and 25 ml of 65 % nitric acid was added. The flask was put on a heater equipped with condenser and heated for 1 hour. After hydrolysis, the flask contents was filtered. The remaining cellulose on the filter paper was transferred into the flask and the process was repeated twice, the cellulose together with the filter paper was dried at 120°C.The cellulose content was calculated from the following equation (Oakely, 1984; Marzieh and Marjan, 2010)

Cellulose% =  $\underline{Cellulose \, dry \, weight}$  X 100

Sample dry weight

#### 3.27

# 3.7.2 Determination of total Lignin Content

The total lignin content of the wood was determined by the determination of the soluble and insoluble lignin gave the total lignin In the soluble lignin determination, 2.00 g of each wood sample was impregnated with 3 ml of 72 % sulphuric acid and placed in a water bath at a controlled temperature of 30 °C for one hour, after which 68ml of deionized water was added to the sample. The conical flask and its content (sample) was heated in an autoclave at 125 °C for I hour 15 minutes. The conical flask and its content were cooled and the lignin filtered. The insoluble lignin was washed with deionized water until neutral pH and then dried in an oven at a temperature of 80 °C until a constant weight. The lignin content was calculated by the following foimular: (TAPPI, 1988).

IL= <u>W Lignin</u> X 100

W fibre

(3.28)

Where IL = Insoluble lignin content (%)

W lignin = Oven-dry weight of insoluble lignin (g)

W fibre = Oven -dry weight of wood fibers (g)

The filtrate obtained from the insoluble lignin was used to determine the soluble lignin content in sulphuric acid by spectrophtometric method. In this method. 5 ml of 3 % sulphuric acid was added to 5ml of the insoluble lignin filtrate. A UV spectrophotometer was used to measure the

absorbance of the solution at a wavelength of 205 nm. The soluble lignin content was calculated by the following expression

$$SL = \underline{CV} X$$

100 3.29

1000 X W fibre

Where SL = soluble lignin conlent (%)

C =concentration of soluble lignin in the filtrate (g/l).

V = total volume of the filtrate (ml)

W fibre = oven-dry weight of wood fibers (g)

The concentration of soluble lignin in the filtrate (C) is given by

$$C = \underline{A} \times \underline{V \text{ final}}$$
110 V initial
3.30

Where A = absorbance at a wavelength of 205 nm.

V final = final volume of the solution (ml)

V initial = initial volume of the solution (ml)

The total lignin content was obtained by the addition of insoluble and soluble lignin obtained by both methods.

TL = IL + SL

Where TL - total lignin

1L= insoluble lignin

SL = soluble lignin

# 3.7.3 Determination of hemicellulose.

Hemicellusose are non-cellulose, non-pectic cell wall polysaccharides. They are categorized under unavailable carbohydrate" since they are not split by the digestive enzymes of the human system. The neutral detergent solution was prepared by weighing I8.6l g of disodium ethylenediamine tetraacetate and 6.81 g of sodium borate decahydrate into 1000 ml of beaker and dissolved in a 200 ml of distilled water by heating. To this a 150 ml solution containing 30 g of sodium Lauryl sulphate, 10 mls of 2-ethanol and 100 ml solution containing 4.5 g of disodium hydrogen phosphate was added. The volume was made up to 1000 ml and the pH of the solution was at pH7. To 1.0 g of each wood powder in a refluxing flask, 10 ml of cold neutral detergent solution was added followed by 0.5 g sodium sulphate. The mixture was heated to boiling and refluxed for 60 minutes. The solution was filtered through a whatman

filter paper No 42 (125 mm) and the residue in the paper washed twice with acetone. The filter paper with the residue was dried in an oven at a temperature of 100 °C for 8 hours. The filter paper and its content were cooled in a dessicator and weighed (Goering and Vansoest, 1975). Hemi cellulose was thus

calculated as

# **3.8** Elemental content of the fifty tropical timbers studied

# 3.8.1 determination of elemental content

There are three stages normally adopted in the elemental analyses

- (i) Ashing the sample,
- (ii) Digestion of the sample and
- (iii) Analysis of the elements using the Atomic Absorption Spectrophotometer (AAS),Ashing of the sample: The wood sample was ashed as described under the ash content determination.

**Digestion of the sample:** The ash content was digested in the crucible with 20 ml  $HNO_3/HClO_4$  in the ratio of 2.1 mixture and covered with petridish heated for 40 mins. The whole content was allowed to cool and flfrered to 50 ml volumetic flask. The digest was diluted to 50ml with 0.5M HC1 and heavy metals were finally determined by using Atomic

Absorption Spectraphotometer,

Analysis of the elements: The trace metals were analyzed using AAS - Atomic Absorption Spectrophotomter

# **3.8.2** Preparation of stock solutions (1000 ppm)

1000ppm stock solution was prepared by weighing 1g of metal or its equivalent salt. The salt was dissolved in 20 ml of 1:1 HCl in distilled water or in dilute acid or base. The solution was transfered into 1 litre standared flask and was made up to the mark with 1 HCl to obtain the 1mg/ml stock.

Metal	Reagent	Weighing	Primary solvent
Al	Al metal	1.000	2 ml conc. HC1
Ba	BaCl <sub>2-</sub> H <sub>2</sub> O	1.779	200 m I water 1.5ml conc HNO <sub>3</sub>
Cd	Cd metal	1.000	Minimum volume of 1:1HC1
Co	$CO_2O_3$	1.407	200 ml hot conc, HCl
Cr	$K_2Cr_2O_7$	2. <b>S</b> 28	200 ml water conc. HNO <sub>3</sub>
			+1.5ml
Cu	Cu metal	1.000	15 ml 1:1HNO <sub>3</sub>
Fe	Fe wire	1.000	50 ml 1:1 HNO <sub>3</sub>
Мо	MoO <sub>3</sub>	1.500	10 % HCl
Mn	MnSO <sub>2-</sub> H <sub>2</sub> O	3.076	200 ml water + 1.5ml conc. HNO <sub>3</sub>
Ni	Ni O	1.273	Minimum volume of 10% (v/v) IIC1
Pb	$Pb(NO_3)_2$	1.598	200 ml water + 1.5 conc. $HNO_3$
			ml
Si	Na <sub>2</sub> SiO <sub>3</sub> .6H <sub>2</sub> O	10.12	Water
Sn	Sn metal	1.000	100 ml conc. HC1
V	NH <sub>2</sub> VO <sub>3</sub>	2.296	800 ml water to 10 conc. HNO <sub>3</sub>
			ml
Zn	Zn metal	1.000	20 ml 1:1 HC1.

Table 3.1: Stock Solutions used

# **3.8.3** Preparation of working solution

A mixed standard solution of Zn, (I ppm), Cd (2 ppm), Cr and Mn (3 ppm), Co, Cu, Fe, Ni (5 ppm) and Pb (20 ppm) was prepared by pipetting specific volumes of each stock solution as follows: Zn –lml, Cd – 2 ml, Cr and Mn – 3 ml, Co, Cu, Fe and Ni – 5 ml and Pb - 20ml, into a 1 litre flask and was made up with 1:1 HC1.

### **Statistical Analysis**

There are two hypotheses that make up the structure of a hypothesis test. They are the null and alternative hypotheses. The null hypothesis is the statement being tested while the alternative hypothesis is often a hoped for or suspected condition for which we wish to find supportive evidence.

In every hypothesis, the decision rule is to reject the null hypothesis if the calculated test statistics is greater than the tabulated test statistics, otherwise we accept. Or, we reject the null hypothesis if the p-value is less than 0.05, otherwise we accept.

In this study, the test statistic is the F-distribution and the statistical technique used is the twoway analysis of variance (ANOVA) technique without interaction. The factors involved are as follows:

- 1. Botanical plants versus phytochemical analysis.
- 2. Botanical plants versus proximate analysis of wood.
- 3. Botanical plants versus cellulose, hemicellulose and lignin.
- 4. Botanical plants versus elemental contents.
- 5. Botanical plants versus chemical characterization.

The null and alternative hypothesis for factors in number 1 for example is

H<sub>0</sub>: There are no significant differences in the botanical plants and the phytochemical analysis

H<sub>1</sub>: There are significant differences in the botanical plants and the phytochemical analysis.

Test statistic: F-test

Decision rule: We reject the null hypothesis if the F-calculated is greater than the F-tabulated, otherwise we accept. Or, we reject the null hypothesis if the p-value is less than 0.05.

If the null hypothesis is rejected, a multiple comparison test is conducted to separate the significant variables from the non-significant ones and consequently rank them in the order of magnitude.

Below are the results of the summaries of the multiple comparison test so conducted. See appendix

# **CHAPTER FOUR**

# **Results and Discussions**

Names of selected timbers, locations where they are obtained an results of phytochemical are shown in Tables 4.1 - 4.4.and figure 4.1-4.9

# Table 4.1 Names of the Selected Fifty Tropical Timbers from Nigeria

NO	BOTANIC NAME	1GBO MAME	YORUBA –NAME	HAUSA NAME	LOCATION
1	Brachysteria Nigeria	Ufi	Akolodo	Ojweb	Amaigbo town in umuahia South L G A abia state
2	Hamoa klaineana	Gova	Guafia	Gwaabaa	
3	Pteracarpiix soyouxi	Oha	Elemi		
4	Garcima kola	Ubeoyibo	Apoasi	Namijin kadai	
5	Lophura lanceolata	Okopia	Iponhon		
6	Albuzia zygia	Ngwu	Ngwu	Gamba	Mamu river in ugwuoba L.G.A. of Anambra State
7	Brachystigtia eureconya	Achi	Akolodo	Etare	
S	Ceitis zenkeri	Ubia	Sanminu	Babbaaoleemu	
9	Cola gigantia	Ebenebe	Owariwo	Karamga	
10	Naulear diderrichii	Ubum	Opepe	Owoso	
11	Anacardium occidentalis	Kashuu	Kaju	K.anju	
12	Irvingia gabonensis	Ugiri	Oro	Ogboin	
13	A Ibizia ferrugines	Ngwu	Ayinre oga	Uwowe	
14	Azadirachta indica	Dogoyalu	Dogoyaru	Dogonyaro	Markurdi in markurdi L.G.A Benue State
15	Canarium schwafituhii	Ube okpoko	Orogbo	Efiat	
16	Hevea brasiliensis	Cacia	Eko-omode	Gabaruwa	
17	Barteria fistulosa	Ogbu	Egele, emile	Nonankuchiya	Ekiti State
18	Tetraplura terapera	Nkwu/Oshosho	Igi-ope	Kwakwar	
19	Pyenanthus angolensis	Okwe	Omoeru or erima	Wamankumi	
20	Dialum guineense	Icheku	Awin	Tsamiyar	
21	Delonix regia	Igboro			Sakpoba forest in Izzi

L.G.A Ebonyi State

22	Newboudia laevis	Ogilisi	Akoko	Abaduruku	
23	Mansonia altissima	Mangoro	Mangolo Mangwaro		
24	Isoberlina tomensosa	Uboba	Baba	Faradoka	
25	Alstonia congensis	Egbu			Okada in okada L.G.A
26	Ficus elastic	Ogbu			Edo State
27	Anogeissus eiocapus	Akioyibo	Ayin	Kwaaattaaagara	
28	Naulea popeguinii	Echichi	Opepe/ologbosere	Minjirgaa	
29	Vitex doniana	Uchakuru	Ori nla	Dinyar	
30	Triplochiton	Okpo	Obeche		Iva Valley Umuabi forest
31	Khaya senegalensis	Ono	Aganwo	Madachi	In Udi L.G.A Enugu state
32	Tectona grandis	Egboku			
33	Irvingia grandifilio	Ogbono/Ugiri	Oro abeja	Goronobiri	
34	Terminatlia superba	Edo	Afara	Gbarada	
35	Baphia nitida	aboshi ojii	Irosun	Arhua	Mgbidi Forest in
36	Gmelina arborea	Gmelina	Igi Melina	Kalankuwa	Oguta L.G.A Imo
37	Lonchocarpus	Anyasi			State
	Griffonianus	Akpu ogwu	Araba	Okha	
38	Ceiba petandra	Akpudele	Awori	Kurya	Illorin in kwara state
39	Bombax buonopozense	P Opiolo mango			
40	Mangifera indica	Red marima	Opepe	Tafashiya	
41	Xylopia aethiopica	Inyi	Erur	Idonzakara	
42	Khaya ivorensis	Akpoko	Kakandika	Kokochiko	Mirina forest in
43	Oncoba spinosa	Ojo			Ogun State
44	Anihodesta	Orji	Iroko	Loko	
45	Chlorophora excels	Abochi ojii			
46	Garcinia gnetrides		Abo	Swandar	Oyo State
47	Annoa senegalensis	Oghulu	Ofun	Madacu	
48	Manikara obovota	Ukpi	Opepeira	-	
50	daniella olivere	Ekpe minili	Lya	Maje	

S/N	Bontanical name	Saponins	Flaronoids	Resin	Protein	Oil	Cardiac	Acidic	Tannins	Alkaloids	Carbohydrates
							glycoside	compound			
1	Brachystegla	++	++	+++	++	++	+	++	++	+	+
	nigeria										
2	Hamoa klaineana	-	++	+++	++	++	+	++	++	+	+
3	Pteracarpus	++	++	+++	++	++	+	++	++	+	+
	soyouxi										
4	Garcinia kola	+++	++	++	++	++	+	++	++	+	+
5	Lophira	++	++	+++	++	+	-	++	++	+	+
	lanceolata										
6	Albizia	++	++	++	++	++	+	++	++	+	+
	ferrugenia/zygia										
7	Brachystigia	++	++	++	++	++	-	++	++	+	+
	eurecomya										
8	Celtis zaneri	+++	++	++	++	+	-		++	+	+
9	Cola	++	++	+++	++	+	-	++	++	+	+
	gigantia/steroulia										
	oblonga										
10	Cola gigantia/	++	++	+++	++	+	-	++	++	+	+
	steroulia										

# Table 4.3: RESULT OF QUALITATIVE ANALYSIS OF PHYTOCHEMICALS OF THE STUDIED WOOD SAMPLES

NO	Botanical name Sap	onins	Flavonoids	Resin	Protien	Oil Cardiac glycoside	Acidic compound	Tanins	Alkaliods	Carbohydrates Cntd.
11	Naulea diderrichii	++	++	+	++	+ +	++	++	+	+
12	Anacardium occidentale	+	++	++	++	++ -	++	++	+	+
13	Irvingia gabanonesis	++	++	+++	++	+ -	++	++	+	+
14	Albizia ferruginea	+++	-	+	++	+ +	++	++	+	+
15	Azadisachta indica	+	++	+	++	++ +	++	++	+	+
16	Canarium schwanfurthii	+++	++	++	++	++ -	++	++	+	+
17	Hevea brasiliensis/ficys elastic	+	++	-	++	+ -	++	++	+	+
18	Bacteria fistuloca	++	++	-	++	+ -	++	++	+	+
19	Tetraplurs tetraapera	++	++	-	++	+ -	++	+++	+	+
20	Pycanthus anglolensis	++	++	++	++	++ +	++	++	+	+
21	Dialum gwineense	+	++	+	++	+ +	++	++	+	+
22	Delonix regia	++	++	+	++	+ +	++	++	+	+
23	Newbodia laevus	+	++	+	++	+ -	++		-	+

Tab	le 4.3: RESULT OF	QUAL	ITATIVE A	NALYS	IS OF PH	IYTOCHEMI	CALS OF TH	E STUDIED W	OOD SAM	PLES	
NO	Botanical name Sap	onins	Flavonoids	Resin	Protien	Oil Cardiac	e Acidic com	pound Tanins	Alkaliods	Carbohydrates	Cntd.
24	Mansonia altissima	-	++	++	++	++ +	++	++	+	+	
25	Isoberlina tomensosa	-	++	++	++	++ +	++	++	+	+	
26	Alberlina tomensosa	-	++	-	++	++ -	++	++	-	+	
27	Alsotina Cogenis	+	++	+	++	++ -	++	+++	-	+	
28	Anogeissus eiocapus	+	++	++	++	++ +	++	++	+	+	
29	Naulea popeuinii	+++	++	++	++	++ +	++	+++	+	+	
30	Vitex doniana	-	++	-	++	++ -	++	++	-	+	
31	Triplochiton scleroxylon	-	++	-	++	+ -	++	++	-	+	
32	Khaya senegalensis	++	++	++	++	+ +	++	++	+	+	
33	Tactona grandis	++	++	++	++	++ +	++	++	+	+	
34	Irvingia gabonensis	++	++	+++	++	+ +	++	+++	+	+	
35	Terminatlia superba	+	++	+	++	+ -	++	++	-	+	
36	Pyenantus angolensis	-	++	++	++	+ +	++	++	-	+	
37	Gemelina arborea	-	++	+	++	++	+	++	++	+ +	

Bota	inical name Sapor	nins F	Flavonoids	Resin Prot	ien	Oil	Cardiac	Acidic	Tanins	Alkaliods Carbohydrates
							glycoside	compound		
38	Lonchocarpus	+++	++	++	++	+	+	++	++	+ +
	griffonianus									
39	Ceiba petandra	-	++	++	++	+	+	++	+++	+ +
40	Bombax	-	++	+	++	+	+	++	++	+ +
	buonopozense									
41	Xylopia aethiopica	++	++	+	++	++	+	++	++	+ +
42	Khaya	++	++	+	++	++	+	++	++	- +
	ovorensis/Khya									
	grandilohala									
43	Terminatla superba	+++	++	+++	++	++	+	++	++	+ +
44	Anthodesta	+	++	++	++	+	+	++	++	+ +
	dejenelensis									
45	Chlorophora excelsa	ı ++	++	+	++	+	-	++	++	- +
46	Hannoa klaineana	+	++	++	++	+	+	++	++	+ +
47	Annoa seneglensis	+	++	+	++	+	-	++	++	+ +
48	Manikara Obovota	+++	++	++	++	+	-	++	++	+ +
49	Nauclea didrichii	+++	++	+	++	++	-	++	++	+ +
50	Daniellia Oliveri	+	++	++	++	+	+	++	++	+ +

++ = Present

+++ = Strongly present

-

Botanical Names	Saponin (%)	.Flavonoid (%)	Resin (%)	Protein (%)	Oil (%)	Cardiac Glycos (mg/100g)	Tannin (mg/g)	Alkaloid %	Carbohydrates (mg/g)
1.Brachystegla nigeria	1.80	0.96	2.29	8.40	1.20	0.57	681	0.026	1.50
2. Hamoa klaineana	Bdl	0.77	2.06	9.20	1.04	0.86	100	0.041	1.62
3. Pteracarpus soyouxi	1.45	0.86	2.07	9.00	1.07	0.39	870	0.011	0.91
4.Garcinia kola	2.01	0.34	1.69	8.70	0.96	0.91	987	0.032	0.95
5. Lophura lanceolata	1.95	0.34	2.03	8.80	1.05	Bdl	567	0.021	1.42
6.Albuia ferrugerua/zjgia	1.35	0.65	1.09	8.60	1.01	0.69	234	0.033	1.56
7. Brachystigia eurecomya	1.65	0.38	1.61	9.40	0.66	Bdl	676	0.012	1.60
8. Ceitis zenkeri	2.25	0.26	1.87	9.10	0.87	Bdl	567	0.023	1.64
9. Cola gigantia	1.02	0.31	2.10	10.00	0.92	Bdl	876	0.044	1.30
10. Nauclea diderrichii	1.41	0.46	0.94	7.90	1.41	0.72	908	0.036	1.44

Botanical Names	Saponin (%)		.Flavonoid (%)	Resin (%)	Protein (%)	Oil (%)	Cardi Glyco (mg/1	Cardiac Glycos (mg/100g)		Alkaloid %
11.Anacardium occidenichii	0.94	0.71	1.37	8.60	0.65	Bdl	9.87	0.017	1.67	
12. Iruingia gabanonesis	1.23	0.60	2.21	8.90	0.98	Bdl	453	0.019	1.63	
13. Aibizia ferruginea	2.10	Bdl	0.86	10.20	1.03	0.82	234	0.024	0.96	
14.Azadirachta indica	0.69	0.37	0.76	8.30	1.40	0.49	213	0.051	0.94	
15.Canarium schwafurihii	2.34	0.49	1.56	8.70	1.43	Bdl	876	0.096	0.92	
16. Hevea brasiliensis	0.76	0.89	Bdl	10.50	0.91	Bdl	564	0.072	1.10	
17.Bacteria fistulosa	1.35	0.52	Bdl	7.60	0.76	Bdl	765	0.016	1.50	
18.Tetraplura terapera	1.62	0.49	Bdl	8.30	0.83	Bdl	654	0.047	1.60	
19. Pyenanthus angolensis	1.87	0.91	1.27	9.30	1.81	0.61	680	0.061	1.23	
20.Dialum gwineense	0.78	0.73	0.98	9.10	0.69	0.84	765	0.068	1.42	
21.Delonix regia	1.38	0.62	0.65	8.70	0.60	0.56	456	0.026	1.65	
2.Newboudia laevis	1.21	0.79	1.21	11.10	0.41	Bdl	500	Bdl	1.56	
23.Mansonia altissima	Bdl	0.93	1.03	8.80	1.06	0.68	565	0.021	1.44	
24. Isoberlina tomensosa	Bdl	0.93	1.61	9.30	1.02	0.37	690	0.032	1.23	
25. Alstonia congensis	Bdl	0.76	Bdl	8.90	1.04	Bdl	987	Bdl	1.23	
26.Ficus platyphylia	0.96	5 0.8	39 0.96	9.1	10	1.82	Bdl	765	Bdl 0.	91
27.Anogeissus eiocarpus	0.72	2 0.6	55 1.34	8.2	20	1.23	0.87	876	0.011 0.	95

# Table 4.4: Result of quantitative phytochemical analysis Continued

28. Naulea popeguinii		2.40	0.74	1.16	9.1	10	1.40	0.69	768	0.026	1.34
29. Vitex doniana		Bdl	0.61	Bdl	7.3	30	1.01	Bdl	908	Bdl	1.32
30. Triplochiton scleroxy	vlon	Bdl	0.72	Bdl	9.1	10	0.93	Bdl	987	Bdl	1.67
31. Khaya senegalensis		1.67	0.76	0.57	7.6	50	0.78	0.48	906	0.016	1.23
32. Tectona grandis		1.38	0.89	1.47	12	.10	1.32	0.63	765	0.042	1.43
33. Irvingia gabonensis		1.72	0.65	2.11	9.3	30	0.91	0.46	565	0.014	0.81
34.Terminatlia superb		0.25	0.74	0.72	8.7	70	0.31	Bdl	876	Bdl	0.98
35. Pycanantu angolensi	s	Bdl	0.61	1.08	8.9	<del>9</del> 0	0.41	0.94	909	Bdl	0.93
36. Gmelina arborea		Bdl	0.72	0.89	11	.30	1.02	0.72	987	0.017	0.91
37.Lonchocarpugriffonic	inus	2.12	0.66	1.19	7.6	50	0.29	0.38	986	0.027	1.23
38.Ceiba petandra		Bdl	0.76	1.22	8.7	70	0.91	0.47	765	0.013	1.20
39.Bombax buonopozens	se	Bdl	0.96	0.67	10	.60	0.69	0.82	678	0.111	1.32
40. Mangifera indica	Bdl	0.75	1.2	9	10.80	0.78	0.76	680	0.008	1.45	5
41.Xlopia aethiopica	1.32	0.26	0.9	1	9.50	1.79	0.54	670	0.036	1.42	2
42. Khaya ivorensis	1.71	0.82	0.78	8	7.90	1.01	0.48	986	Bd	l 1.23	3
43. Oncoba spinosa	2.21	0.24	2.13	3	9.30	1.39	0.59	876	0.041	1.52	2
44.Anlhodest dejenalensis	0.91	0.38	1.10	5	8.60	0.44	0.97	911	0.02	1	3
45.Chlorophora excels	1.69	0.93	0.74	4	8.80	0.96	Bdl	823	Bdl	0.90	5
46. Hannoa klaineana	0.86	0.49	1.34	4	9.20	0.78	0.64	843	0.03	2 0.93	3

% detected Range	0.25-2.40 (Terminat Superba,	66 ta naulea	98 0.24-0.96 (Brachystegia nigeria, Bouch au	72 0.57-2.29 (khaya Senegalensis,	100 7.30-12.10 (Vitex doniana, Tectona	100 0.29-1.82 (Lonchocarpu griftonianus, Ficus	44 0.37-0.97 (Isoberlina tomensosa,	100 100-999 (Hamoo klainiana,	1.23 74 0.01-0.11 ( <i>Manjifera</i> <i>indica</i> ,	100 0.81-1.67 (Irvingia gabonensis, Anacardium
50. Daniellia olive	r (	0.91	0.43	1.41	7.99	0.92	0.67	867	0.91 0.019 1.23	
49. Nauclea dideri	chii 2	2.14	0.86	0.93	9.20	1.07	Bdl	676	0.99 0.041	
48. Manikara obov	vata Z	2.01	0.42	1.08	8.20	0.86	Bdl	999	0.98 0.022	
47. Annoa senegal	ensis (	0.71	0.86	0.67	9.10	0.97	Bdl	932	0.037	

# Bdl= Below detection limit

`

# Table 4.5:

Summary of multiple comparisons for Phytochemicals

		Leader	Rank
SaponinVs Flavonoid 0.49	96	Saponin	4
,, ,, Protein -7.8	948		
,, ,, CardialGlycos 0.74	46		
,, ,, Carbohydrates 0.99	28		
Flavonoid VsSaponin -0.4	996		
,, ,, Resin -0.5	042		
,, ,, Protein -8.3	944		
" " Oil -0.3	388		
" " CardialGlycos 0.24	50	Flavoid	7
,, ,, Alkaloid 0.61	22		
,, ,, Carbohydrates 0.49	32		
Renin Vs Flavonoid 0.50	42	Renin	3
" " Protein -7.8	902		
" " CardialGlycos 0.74	92		
" " Alkaloid 1.11	64		
" " Carbohydrates 0.99	74		
Protein Vs Saponin 7.89	48		
	44		
	02	Protein	1
	56		-
	94		
Alkaloid 9.00	66		
, , , , Carbohydrates 8.88	76		
Oil Vs Flavonoid 0.33	88	Oil	5
Protein -8 0	556	0 II	5
CardialGlycos 0.58	38		
Alkaloid 0.95	10		
Carbohydrates	20		
CardialGlycosVs Saponin -0.74	446		
Flavonoid -0.2	450	Flavonoid	7
$\begin{array}{c} n \\ n $	492	1 luvoliolu	,
Protein -8.6	394		
$\int_{-0.5}^{\infty}$	838		
Carbohydrates 0.24	82		
,, ,, Caroonyarates 0.24	02		
Alkaloid Vs Saponin -1.1	18		
,, ,, Flavonoid -0.6	122	Flavonoid	2
" " Renin -1.1	164		
., ,, Protein -9.0	066		
,, ,, Oil -0.9	510		
carbohydrates Vs Saponin -0.9	928		
, Flavonoid -0.4	932		
., , Resin -0.9	974		
	876		
	20		
,, CardialGlycos -0.24	482	CardialGlycos	6

The anova result showed that phytochemicals are significant (p<-.05). Therefore multiple comparisons was carried out among the phytochemical. Each phytochemical was compared among others and the mean difference were obtained where some are significant as shown in the p-value and also with asterisks. Smmary of multiple comparison for phytochemicals was carried out taking the least significant difference of the mean from which the leader was found. The leaders obtained were then ranked to get the most significant followed by others. Protein is most significant, followed by Flavonoid and lastly cardiac glycolside.

## 4.1 RESULTS OF THE SAPONIN CONTENT OF THE WOOD SAMPLES

The quantitative phytochemical analysis carried out on the selected Nigeria timbers showed saponing content to be in the range of 0.25-2.40 % (table 4.4 and fig 4.1). the wood Naulea Popeguiniiwith serial number 28 has the highest saponning content of 2.40%. whereas the wood Termunartia superb (S/N 34) has the lowest content of 0.25.Moving in descending odder we have the following trend: 28>15>8>43>49>37>13>4,48>5>19>33>42>45>31>7>18>3>10>21,32>6,I7>41,12>9>26>I1>44, 50>46>20>16>27>47>14>34

The values for some of the wood samples obtained such as 2.40%, 2.34%, 2.25%, 2.21% 2.14%, 2.12%, 2.10% and 2.01%, for wood numbers 28, 15, 8, 43, 49, 37, 13, 4 and 48 respectively are similar to the experimental values of leafy content of saponin reported by Eleazu *et al.*, (2012), whose value was 2.10 %. Values ranging between 0.25% -1.95% are similar to the experimental values of leafy plant saponin by Akharaiyi *et al.*, (2012) and Eleazu *et al.*, (2012) whose values ranged between 0.039% to 1.60%. The levels of saponins in the timbers studied were higher than 0.01% and 0.03% reported for *mandora myristica* and *xylopia aethiopica* respectively (Okwu, 2004). Some woods / timbers with numbers 2, 23, 24, 25, 29, 30, 35, 36, 38, 39, 40 have values below detectable limits. Timbers with high concentrations of saponins are more beneficial and economical in soap industries and also in pharmaceutical industries because of their soap-like nature and medicinal properties than those with low percentage of saponin contents.



Figure 4.1 Saponin content of Wood samples

#### **4.2 Results of the flavonoid content of the wood samples**

The term flavonoid embraces all compounds whose structures are based on the flavones. Anthocyanin belongs to this group of compounds. Anthocyanins are water soluble natural plant pigments. They are responsible for the large variety of colours in plants. Flavonoids exhibit estrogenic antioxidant and anticancer activites. Flavonoids are antioxidants and free radical scavengers which prevent oxidation cell damage and also protects against all stages of carcinogensis (Salah, 1995., Del Rio *et al.*, 1997). Flavonoids in intestinal track lower the risk of heart diseases. As antioxidant, flavoniod provide anti- inflammatory actions (Okwu, 2001). The anti inflammatory properties of some flavonoids have been attributed to their ability to inhibit the production of activated macrophages (Scuro *et al.*, 2004). Flavoniods exhibit estrogenic antioxidants which prevent oxidative cell damage and also protect against bacterial dehydration, (Salah *et al.*, 1995).

The results of experiment in Table 4.4 and figure 4.2 showed that the percentage flavonoid in the timber species ranged between 0. 24 % to 0.96 %. Wood number 1 (Brachystegia nigeria) and 39 (Bombax *buanopozense*) have the highest flavonoid content of 0.96 % while wood number 43 (Oncomba spinosa) has the lowest flavonoid content of 0.24 %. The following *timbers:* 1,39, (Brachystegia nigeria, Bombax buanopozense 0.96 %), 26(Ficus elastica 0.89 %), 45(Chhrophora excels 0.93 %), 19 (Pyenanthus angolensis 0.91 %), 23(Mansonia altissima 0.93 %),24 (Isoberlina tomensosa 0.93 %), 32,16 (Tectona grandis, Hevea brasiliences 0.89 %) 42(Khaya ivorensis 0.82 %), 2(Hamoa klaineana 0.77%), 11(Anacardium, Occidentale 0.71%) 20(Dialum guineense 0.73%) %) 22(Ne\vboudia laevis 0.79 %), 33(Irvingia gabonensix 0.72 %), 38,25, 31(Ceiba petendra, Alstonia congensis and Khaya senegalensis, respectively 0.76 %), 28(Naulea popeguinii 0.74 %), 30, 36(Triphchiton sceroxylon, Gmelina, arburea 0.72 %), 34(Termmatlia superba 0.74 %), 40 (Mangifera indica 0.75%) have higher flavonoid content. The average percentage of flavonoid content yield in the various woods were observed in 6 (Albuia ferrugerua 0.65%), 12(Irvingia gabonensis 0.60%), 21(Detonix regia 0.62%), 27,33 (Anogeissus eiocapus, Irvingia grandifolio 0.65%), 29(Vitex doniaua 0.65%). 35(Baphia nitida 0.61%), 37(Lonchocarpus 0.66%), 17 (Bacteria fistulosa 0.52%), while low percentage content of flavoniod was observed in the following wood species: 10(Naulea diderrichii 0.48% 0.49%), 15(Canarium schwafurihii 0.49%) 18(Tetraplura terapera 0.49%), 46(Garcinia gnetrides 0.49%), 48(Manikara obovata 0.42%, 50(Daniella oliveri 0.43%), 4(Garcinia cola 034%), 5(Lophura lanceoata 0.34%), 7

(Brachystigia evrecomya 0.38%), 9(Colagigentia 0.31%), 14 (Azadirachta indica 0.37%), 44(Anlhodesta dejenalensis 0.38%), 8(Ceitis zenkeri 0.26%), 41(Xylopia aethiopica 0.26%), 43(Oncoba spinosa 0.24%). Thus the values of the flavonoid contents of the wood species studied in this research were not similar (lower) to 1.44% by Compaore *et al.*, (2011) according to his experiments on both leaves and seeds of the plants. Wood species number 13 was below detectable limit. Flavonoids are vital in combating the free radicals that are constantly forming in our bodies due to oxidation. Free radicals damage the cells in our body, which could lead to oxidative stress and disturbance in cell metaboliism by curing the activity of free radicals in our body and by so doing we can slow down the process that causes aging and live a longer and healthier life.



Figure 4.2 Flavonoid content of Wood samples

#### 4.3 RESINS

Resins are among the wood extractives. Composite wood products comprise different

resins, fungicides and pesticides. Some experiments on varied resinous longleaf pine specimens indicate an increase in strength due to the resin which increases the strength when dry. Such resinsaturated heartwood is called "Fat Lighter". Structures built of fat lighter are almost impervious to rot and termites, however, they are very flammable. Wood impregnated with crude resin and dried is also greatly increased in strength. The resin content ranged from 0.57 -2.29% indicating that the plant species are almost impervious to rot and termites (figure 4.3.) This suggests that the resins imparted flammability properties of the wood species. Flammability of the wood samples is attributed to the presence of resins (Eboatu, 1992).

Resins are substances produced by plants for special purposes e.g. for sealing wounds. They are generally characterized by having multiple systems of carbon rings and low oxygen content. Examples of acids isolated from resins include the following: Abietic acid, pimaric acid, neoabietic acid, isopimaric acid and cinnamic acid. Resin is a natural preservative to plant. The dark colour of heart wood is usually due to resin or gum. Resins are natural preservatives. Resin is synthetic or naturally occurring polymer. Synthetic resins are used in making plastics. Natural resins are acidic chemicals secreted by many trees into ducts or canals. They are found either as brittle glassy substances or dissolved in essential oils. Their functions are probably similar to those of gums and mucilage. Resins are natural preservatives, they impart flammability properties to the wood species. They are substances produced by plants for special purposes e.g. for sealing wounds. They are generally characterized by having multiple systems of carbon rings and low oxygen content. The values ranged from below detection limit (Bdl) to 2.29 unit with (*Brachystegia nigeria*) having the highest value of 2.29 Unit while 31 (*Khuya, senegalensis*) has the lowest value of 0.57(fig. 4.3). Others with medium values are: *Anacardium occidentalisa* (1.37 Unit), *Isoberlina tomensosa* (1.61), and *Iruingia gabanonesis* (2.21unit).



Figure 4.3: Resin content of wood samples

#### **4.4 Results of the protein content**

From the percentage protein content results in Table 4.4 and Figure 4.4, it was observed that the percentage protein content ranged from 7.30 to 12.10% with wood specie number 32(Tectona grandis) having the highest protein content of 12.10%) followed by 22(Newboudia laevis 11.10%). 36(Gmelina arborea 11.30%), 9(Cola gigantia 10.00%), 16(Hevea brasiliensis 10.50%), 19(Bombax buonopazense 10.60%), 40(Mangifera indica 10.80%). The average crude protein content yield in the various woods was observed in 2(Hamoa klaineana 9.20%), 3(Pteracarpus soyouxi 9.00%), 7(Brachystigia eurecomya 9.40%), 8(Ceitis zenkeri 9.10%). 19(Pyenanthus angolensis 9.30%), 20(Dialum guineense 9.10%). 24(Isoberlina tomensosa 9.30%), 26(Ficus elastica 9.10%), 28(Naulea popeguinii 9.10%), 30(Triplochiton scleroxylon 9.10%), 33(Irvingia grandifolio 9.30%), 41(Xylopia aethiopica 9.50%), 43(Oncoba spinosa 9.30%), 46(Garcinia gnetrides 9.20%), 47(Annoa senegalensis 9.10%), 49(Naulea latifollio 9.20%), 1(B rachystegia nigeria 8.40%), 5(Lophura lanceolata 8.70%), 6(Albzigia zigia 8.60%), 11(Anacardium occidentale 8.60%), 12(Iruingia gabanonesis 8.90%), 14(Azadirachta indica 8.30%), 15 (Canarium schwafurihii 8.70%), 18(Tetraplura terapera 3.30%), 21(Delonix regia 8.70%), 23(Mansonia altissima 8.80%), 25(Alstonia congensis 8.90%), 27(Anogeissus eiocapus 8.20%), 34(Terminatlia superba 8.70%), 35(Baphia nitida 8.90%), 38(Ceiba petandra 8.70%), 44(Anlhodesta dejenalensis 8.60%), 45(Chlorophora excelsa 8.80%), and 48(Manikara obovata 8.20%). The lowest protein content was observed in the wood specie number 29(Vitex doniana 7.30) followed by 10(Naulea diderrichii 7.90%), 17(Barteria fistulosa 7.60%) 31(Khaya senegalensis 7.60%), 37(Lonchocarpus griffonianus 7.60%) 42(Khaya ivorensi 7.90%), 50(Daniella oliveri 7.99%). The results of this research showed that the values of all the wood species obtained from the experiment are low compared to the experimental values of plant seeds by Lohlum et al., (2010) whose protein value was 29.89% and Compaore et al., (2011) whose protein value was 35.37%. The protein content of the fifty Nigerian timbers were higher than the experimental values of plant seed by Adesuyi et al. (2011) whose value was 1.86%. Thus the protein values for both wood and seed of the plant may not be similar according to the experiments on the seed of the plants which may be as a result of the fact that proteins are higher in some seeds than in woods and also lower in some seeds than in woods. All the studied wood species contained protein. Proteins are polymer and their monomeric units are the amino acids. They are biochemical compounds consisting of one or more polypeptides, A polypeptide is a single linear polymer chain

of amino acids bonded together by peptide bonds between the carbonyl and amino groups. The values of protein recorded in this study were quite encouraging indicating that the wood species are rich in protein nutrient. When amino acids react with themselves they form products called peptides. When the molecular weight of a polypeptide exceeds 10,000 amu, the polypeptide is by definition called a protein. In living organisms, proteins perform many functions including the transport of nutrient, participation in the structural components of cells and action as enzyme or biochemical catalysts. Although the percentage composition of protein in these timbers is low, they can serve as sources of protein supplement. The protein content showed that it could be incorporated in the diets of animals.


Figure 4.4: Protein content of Wood samples

## 4.5 Results of the oil content of the wood samples

Fats and oil are used as solvents in the preparation of intramuscular injections for example sesanine oil, others have medicinal actions, for example; castor oil as (catharrinic), codliver oil (as an anthracitic) and olive oil (as an emollient). In this study, oil content ranged from 0.29% to 1.82%. The tropical timber number 34 has the lowest oil content while the tropical timber number 19 has the highest oil content. Generally, the percent oil yield from the timbers were lower than the percentage oil yield from other parts of a tree like the seed and seed coat (Agwu, 2006). The percentage oil content of the tropical timbers indicated that they could not be used in industries for the production of some industrial products such as alkyd resins for paints or varnish, soap, cream, lotion, plasticizers for plastics etc. The oil content in the timber species serves as essential emulsifier for a number of drug preparation. According to Fahy et al., (2009) the main function of oils include energy storage. The oils are non-drying oil. The result of the percentage oil yield of the wood species in Table 4.4 and fig. 4.5 showed that the percentage oil yield ranged between 0.29 - 1.82%, The wood specie number  $26(Ficus \ elastica)$  has the highest oil content of 1.82%followed by: 1 (Brachystegia nigeria 1.20%), 2 (Hamoa klaineana 1.04%), 3 (Pteracarpus soyouxi 1.07%), 5 (Lophura lanceolata 1.05%), 6 (Albizia latifolia 1.01%), 10 (Naulea diderrichii 1.41%) 13 (Albizia ferruginea 1.03%), 14 (Aradirachia indica 1.40%), 15 (Canarium schwafitrihii 1.43%), 19 (Pyenanthus angolensis 1.81%), 23 (Mansonia altissima 1.06%), 24 (Isoberlina tomensosa 1.02%). 25 (Alstonia congensis 1.04%), 26 (Ficus elastica 1.82%), 27 (Anogeissus eiocarpus 1.23%) 28 (Naulea popegunii 1.40%) 29 (Vitex doniana 1.01%), 41 (Xylopia aethiapica 1.79%), 42 (Khaya ivorensis 1.01%), 32 (Tectona grandis 1.32%), 36 (Gmelina arborea 1.02%), 43 (Oncoba spinosa 139%) while the lowest percentage oil content was observed in 37 (Lonchocarpus griftonianus 0.29%). Other species with lower values are: 4 (Garcinia kola 0.90%), 7 (Brachystegia eurecomya 0.66%), 8 (Ceitis zenkeri 0.87%), 9 (Cola gigantia 0.92%), 11(Anacardium occidentalis 0.65%), 12 (Irvingia gabonensis 0.98%), 16 (Heveabras brasilensis 0.91%), 17 (Bacteria fistulosa 0.76%), 18 (Tetraplura terapera 0.83%), 20 (Dialum guineense 0.69 %), 21 (Delonix regies 0.60%), 22 (Newboudia laevis 0.41%), 30 (Tripiochiton scleroxylon 0.93%), 31 (Khaya senegalensis 0.78%) 33 (Irvingia gabonensis 0.91%), 34 (Terminatla superb 0.31%) 0.31%) 35(Pycananthus angolensis 0.41%), 37 (Lonchocarpus griffonianus 0.29%), 38 (Ceiba petandra 0.91%), 39 (Bombax buonopozense 0.69%), 40 (Mangifera indico 0,78%), 44 (Anihodcs! a dejanalensis 0.49%), 45 (Chlorophora excelsa 0.96%), 46 (Garcinia gnetrides

0.78%), 47 (Annoa senegalensis 0,97%). 48 (Manikara obovata 0.82%), 50 (Danielia Olivera (0.92%). The result of the research indicated that the values for the wood species obtained from the experiment were very low when compared to the experimental values of seed oil by Lohum et al.,(2010) whose value was 28,61% and by Compaore *et al.*, (2011) whose value was 43.56%, Thus the oil values for both wood and seed part of the plant are not similar according to the experiment on the woody and seedy parts of the plant. The above experiment showed that there is high content of oil in the plant seeds compared to the plant wood. The oils did not solidify at room temperature which showed that they were unsarurated. The low values of the oil yield was because woods are low in fat and oil. This suggests that generally the percentage oil yield from the timbers were lower than the percentage oil yield from other parts of a tree like seed and seed coat. From the values, the oils are non-drying. Fats and oils are the most important lipids found in nature. Lipids are those constituents of animals and plants which are soluble in organic solvents such as ether, chloroform, tetrachloride, benzene, hexane etc., but insoluble in water. They are one of the three major food factors needed for human body and are of great nutritional value. They provide concentrated reserve of energy in animal body for maintaining optimum body temperature. Not only that the edible fats and oils occupy a place of pride in human diet but they also find use as raw material for the manufacture of soaps and synthetic detergents, paints and varnishes, polishes, glycerol, lubricants, drying oils cosmetics, printing inks, linoleum oil and Pharmaceuticals. Wood is resistant to attack of bacteria and fungi due to presence of antiseptic oil (Eboatu, 1992).



Figure 4.5: Oil content of Wood samples

### 4.6 Results of the cardiac glycoside content of the wood Samples

From Table 4.4 and figure 4.6 it showed that the cardiaic glycoside content of the wood samples ranged between 0.37 to 0.97 mg/100 g. The wood specie number 44 (Anihodesta dejenalensis) has the highest cardiac glycoside content of 0.97 mg/100 g followed by 35 (Pycanantus angolensis 0.97 mg/100 g., 4(Garcinia kola 0.91 mg/100 g), 2(Hamoa klaineana 0.86 mg/100 g); 20 (Dialum guineense 0.84 mg/100 g), 13(Albizia ferruginea 0.82 mg/100 g), 27 (Anogeissus eiocarpus 0.87 mg/100 g), 39 (Bombax buonopozense 0.82 mg/100 g), 10 (Naulea diderrichii 0.72 mg/100 g), 36 (Gmelina arborea 0.72 mg/10 0g) 40 (Mangifera indica 0.76 mg/100 g). The average cardiac glycoside content yield in the various woods were observed in 6(Albizia grandifolia 0.69 mg/I00 g), 23 (Mansonia altissima 0.68 mg/100 g), 19 (Pyenanthus angolensis 0.61 mg/100 g), 28 (Naulea popeguinii 0.69 mg/100 g), 32 (Teetona grandis 0.63 mg'100 g), 50 (Daniellia olivcra 0.67 mg/100 g), 46 (Annoa klaineana 0.64 mg/100 g), 1 (Brachystegia nigeria 0.57 mg/100 g), 21 (Delonix regia 0.56 mg/100 g) 43 (Oncoba spinosa 0.59 mg/100 g) and 41 (Xylopia aethopica 0.54 mg/100 g). Lower cardiac glycoside content was observed in 14(Azadirachta indica 0.49 mg/100 g) 31 (Khaya senegalensis 0.48 mg/100 g). 38 (Ceiba petandra 0.47 mg/100g), 42 (Khaya ivorensis 0.48 mg/100 g) and 33 (Irvingia grandifolio 0.46 mg/100 g), while the lowest cardiac glycoside content was observed in 24 (Isoberlina tomensosa 0.37 mg/100 g), 37 (Lonchocarpus griffonianus 0.38 mg/100 g), and 3(Pteracarpus soyouxi 0.39 mg/100 g). Thus the cardiac glycoside value of all the studied wood species obtained from the experiment, were not similar to the experimental values of seed cardiac glycoside by Adesuyi et al., (2011) whose value was 342 mg/100 g and Monago and Akhidue, (2002) whose value was 59.56 mg/100 g. Thus the cardiac glycoside values of both wood and seed of the plant may be different because of the difference in parts of the plant used in the experiment. The seedy part of the plant contains more cardiac glycoside than the woody part of the plant. Glycocide is a cyclic acetal formed by reaction of sugar with another alcohol. A functional group consisting of two ether type oxygen atoms bound to the same carbon  $R_2C(OR^1)_2$ . Glycocides are compounds containing a carbohydrate and a non carbohydrate residue in the same molecule. Cardiac glycosides have been reported to inhibit fungal growth (Edeoga et al., 2005).



Figure 4.6: Cardiac glycoside content of Wood samples

## 4.7 results of the tannin content of the wood samples

Table 4.4 and Figure 4.7 showed that the tannin content of the wood species ranged between 100 Mg/100 g to 999 mg/100 g with wood number 48 (manikara obovata) having the highest tannin content of 999 mg/100 g, followed by 4 (Garcinia kola 987 mg/100 g), 11 (Anacardium occidental 987 mg/100 g): 25 (Alstonia congensis 987 mg/100 g). 36 (Gmelina arborea 987 mg/100 g), 30 (Triplochiton scleroxylon 987 mg/100 g); 37 (Lonchocarpus griffonianus 986 mg/100 g), 42 (Khaya ivorensis 986 mg/100 g), 47 (Annoa senegalensis 932 mg/100 g), 44 (Anihodesta degenalensis 911 mg/100 g), 10 (Naulea diderrichii 908 mg/100 g). 29 (Vitex doniana 908 mg/ 100g), 35 (Pycantus ongolensis 909 mg/100 g), 31 (Khaya senegalensis 906 mg/100 g), 3 (Pteracarpus soyouxi 870 mg/100 g), 9 (Colagigantia 876 mg/100 g), 15 (Canarium schwafurihii 876 mg/100 g), 27 (Anogeissus eiocarpus 876 mg/100 g), 34 (Terminathia superba 876 mg/100 g) 43 (Oncoba spinosa 876 mg/100 g) 46 (Hannoa Klaineana 843 mg. 100 g) 45 (Chlorophora excels 823 mg/100 g), 50 (Daniella olivera 867 mg/100 g), 17 (Bacteria fistulosa 765 mg/100 g), 20 (Dialum guineense 765 mg/100 g), 26 (Ficus platyphylia 765 g/100 g), 28 (Naulea popeguinii 768 mg/100 g), 32 {Tectona grandis 765 mg/100 g) and 38 (Ceiba petandra 765 mg/100 g). The average tannin content in the various woods were observed in 1 (Brachystegia nigeria 681 mg/100 g), 7 (Brachystegia aurecomya. 676 mg/100 g), 18 (Tetraplura terapera 654 mg/100 g), 19 (Pyenanthus angolensis 680 mg/100 g), 24 (Isoberlina tomensosa 690 mg/100 g); 39 (Bombax buonopozense 678 mg/100 g), 40 (Mangifera indica 680 mg/100 g), 41 (xylopia aethiopica 670 mg/100 g), 49 (Naulea 676 mg/100 g), 5 (Lophura Lanceolate 567 mg/100 g), 8 (Ceitis zenkeri 567 mg/100 g), 16 (Hevea brasiliencis 564 mg/100 g), 23 (Mansonia altissima 565 mg/100g), 22 (Newboudia laevis 500 mg/100 g) and 33 (Irvingia gabonensis 565 m/100 g). Low tannin content were observed in 12 (Irvingia gabonensis 453 mg/100 g), 21 (Delonix regia 456 mg/100 g) 6 (Albuzia adianthifolia 234 mg/100 g), 13 (Albizia ferruginea 234 mg/100 g), 14 (Azadirachta indica 213 mg/100g) and the lowest tannin content was observed in 2 (Hamoa Klaineana) with tannin value of 100 mg/100g.

Results of tannin content of the wood species of the fifty woods were remarkably higher than the value 1.38 mg/100g illustrated by Eleazu *et al.* (2012) and 0.342 mg/100 g illustrated by Adesuyi *et al.*, (2011). The reason could be that tannin is more concentrated at the woody part of the plant as shown in Table 4.4 compared to the leafy region as demonstrated by Eleazu *et al.* (2012) and Adesuyi *et al.* (2011). It could also be as a result of the wood's age as stated by Richard and

Peter (1991) in their experiment where older wood gave more tannin contents than the younger ones. From the results, it can be deduced that timber with high content of tannin will be more benefitcial and economical in leather tannin and in the production of dye, wood adhesivcs and most imponantly will find much application in phamarceutical industries because of its astringent properties. Tannins when not properly eliminated in food may inhibit the activity of digestive enzymes and as such decreases the bio availability of such food substance. High tannin content has been reported to decrease the digestivity of carbohydrate in food as well as abdominal discomfort fainting and interferes with absorption of iron and causing carcinogenic effect (Liener, 1980). The high values of tannin in the wood is not surprising since tannin is more concentrated at the woody part of trees. Tannin is a natural preservative of plant. It is said to have astringent antiseptic and invigorating properties.



Figure 4.7 Tannins Contents of Wood samples

### **4.8 results of the alkaloid content of the wood samples**

Alkaloids are naturally organic compounds present in plants. This compounds have basic characters and contain at least one nitrogen atom in a heterocyclic ring (Akpuaka, 2000). Among these compounds are dipiperdine; pyrrolizidine, B-carboline and phenyl ethylamine. Alkaloids have therapeutic significant plant substances. Pure, isolated plant alkaloids and their synthetic derivatives are used as basic medicinal agents for their analgesic antiplasmodic and bactericidal effect (Stary, 1998). They exhibit marked physiological activity when administered to animal even at very small doses (Finar. 2000). From Table 4.4 and Figure 4.8 of fifty Nigerian timbers, alkaloid content ranged from 0.008 -0.11 %. It was observed that wood number 39 (Bombax buonopozense 0.011 %) has the highest percentage alkaloid with value of 0.11 %,15 (Canarium schwafurihii 0.096 %), 19 (Pyenanthus angalensis 0.061 %), 20 (Dialum guineense 0,068 %) and 14 (Azadirachta indica 0.051 %). 40 (Mangifera indica) has the lowest percentage alkaloid content of 0.0108 %), 2 (Hamoa klaineana 0.041 %), 9 (Cola gigantia 0.044 %), 18 (Tetraplura terapera 0.047 %) 32 (tectona grandis 0.042 %), 43 (Oncoba spinosa 0.041 %) and 49 (Naulea diderichii 0.041 %) while most wood have alkaloid content between 0.008 %-0.037 %. Wood species such as 22 {Newboudia laevis}, 25 (Alstonia cogensis), 42 (Khaya Ivorensis) 45 (Chlorophora excelsa) 26 (Ficus elastica). 29 (vitex doniana), 30 (Triplochiton Scletoxylon), 34 (Terminatlia superba) and 35 (Baphia nitida) have values beyond detection limit. Thus the alkaloid values of the fifty Nigerian timbers obtained from experiment were not similar to the experimental values of leafy alkaloid by Kharaiyi et al. (2012) whose value was 1.5 % and Eleazu et al. (2012) and Okwu, 2004 whose value was 9.0 %. Thus, the alkaloid values for wood may not be similar according to the experiments on the leaves of the plant. Alkaloids which are secondary metabolites are group of naturally occurring chemical compounds that contain mostly basic nitrogen atoms (Manske, 1965). and have more pharmacological effects due to their medication as recreational things. Therefore from the above literature, it can be deduced that woods with high percentage of alkaloid content will be very important to pharmaceutical industries than those with low percentage of alkaloid content.



Figure 4.8: Result of Alkaloids content of Wood samples

## 4.9 Results of the carbohydrate content of the wood samples

The result of carbohydrate content in Table 4.4 and figure 4.9 shows that the carbohydrate content of the wood ranged between 0.81 - 1.67 (mg/g). 11 (Anacardium occidentale) and 30 (Triplochiion scleroxylon) have the highest carbohydrate content of 1.67 mg/g. followed by 8 (*Ceitis zenkeri* 1.64mg/g), 2 (*Hamoa klaineana* 1.62mg/g), 7(*Brachystigia eurecomya* 1.60mg/g), 12 (Irvingia gabanonasis 1.63mg/g), 21 (Delonix regia 1.65mg/g), 18 (Tetraplura terapera 1.60 mg/g), 1 (Brachystegia nigeria 1.50 mg/g), 6 (Albizia adianthifolia 1.56 mg/g), 17 (Bacteria fistulosa 1.50 mg/g). 22 (Newboudia laevis 1.56 mg/g) and 43 (Oncoba spinosa 1.52 mg/g). Low carbohydrate content was observed in 5 (Lophura lanceolata 1.42 mg/g), 10 (Naulea diderrrichii 1.44 mg/g) 20 (Dialum guineense 1.42 mg/g), 23 (Mansonia altissima 1.44 mg/g), 32 (Tectona grandis 1. 43 mg/g) 40 (Mangifera indica 1.45 mg/g), and 41 (Xylopia aethiopica 1.42 mg/g). On the other hand the carbohydrate content of most wood species fell within 0.81 mg/g - 1.34 mg/g. 33(Irvingia gabonensis) has the lowest carbohydrate content. From the above results it can be deduced that wood/timber with high carbohydrate content will release more energy than those with low carbohydrate content when consumed, and as such will aid in regulating blood glucose and also breaking down of fatty acids in the blood, to prevent ketosis. The carbohydrate range of values recorded in this study are lower than those recorded by Agwu, 2006 for seed coat of pachystela brevipes. Though the woods have low concentrations, the wood samples can be used as energy sources for food supplements for animal feed. Carbohydrates are polyhydroxy aldehydes or ketone or substances that yield these on hydrolysis e.g. sugar, starch, cellulose They are common source of energy in living organisms with the empirical formula  $Cn(H_2O)n$ .



Figure 4.9: Result of Carbohydrate content of Wood samples

# Table 4.5, Figures 4.10-4.19 Showed the physical properties of Wopodd samples

## Table 4.5: THE PHYSICAL PROPERTIES OF WOOD

	Botanical Names	Moistu	Ash	Specific	Crude	Fibre	Therm	Charring	pН	Porosity	FSP
		re	Conten	gravity	fibre	length	al	Temperat		%	%
		Conten	t %	%	%	(mm)	condu	ure			
		t %					ctivity	oC			
1	Brachystegla	10.8	6.00	0.012	34.25	1.98	9057.0	380-390	5.23	0.068	24.0
	nigeria						0				
2	Hamoa	14.5	5.30	0.016	36.42	1.83	8008.9	364-384	5.06	0.051	27.0
	klaineana						0				
3	Pteracarpus	12.80	3.50	0.014	33.78	1.81	5291.3	370-382	6.72	0.058	26.0
	soyouxi						0				
4	Garcinia kola	13.20	8.00	0.015	35.48	1.55	12076.	379-383	5.20	0.054	28.0
							00				
5	Lophura	16.70	10.50	0.019	37.55	1.57	15854.	380-394	5.05	0.043	28.0
	lanceolata						30				
6	Albuzia	17.00	8.50	0.019	34.79	1.60	12835.	360-381	4.90	0.043	21.0
	ferrugerua/zjgia						30				
7	Brachystigia	11.80	2.80	0.013	34.55	1.65	4230.0	378-390	4.72	0.06	25.5
	eurecomya						0				
8	Ceitis zenkeri	14.90	33.50	0.017	37.20	1.80	50576.	375-390	5.45	0.048	24.0
							30				
9	Cola gigantia	16.50	3.00	0.019	35.60	1.85	4532.0	380-392	62	0.043	27.0
							0				
10	Naulea	16.40	70.00	0.018	38.10	1.81	10566	376-379	6.61	0.046	28.5
	diderrichii						5.00				
11	Anacardium	14.10	0.50	0.016	36.34	1.81	759.30	380-391	5.70	0.051	28.5
	occidentale										
12	Irvingia	14.00	5.00	0.016	37.68	1.75	7551.0	364-370	5.10	0.051	27.0
	gabanonesis						0				

13	Aibizia	18.70	9.60	0.021	36.54	1.60	14498. 368-376	5.02	0.039	24.0
	ferruginea						80			
14	Azadirachta	18.90	1.50	0.021	36.42	1.69	2272.3 370-384	4.10	0.039	25.5
	indica						0			
15	Canarium	22.10	6.8	0.025	38.20	1.97	10268. 360-386	6.25	0.032	21.0
	schwafurihii						00			
16	Hevea	17.50	1.00	0.020	40.12	1.85	1513.0 370-386	5.20	0.041	28.5
	brasiliensis						0			
17	Bacteria fistulosa	17.30	7.90	0.019	40.20	1.92	11932. 374-390	4.55	0.043	26.0
							00			
18	Tetraplura	34.40	18.60	0.039	36.50	1.98	28080. 371-383	5.25	0.021	26.0
	terapera						80			
19	Pyenanthus	16.30	3.00	0.018	35.10	1.95	4532.0 365-387	6.20	0.046	27.0
	angolensis						0			
20	Dialum	14.20	1.50	0.016	37.65	1.85	2272.3 380-390	4.80	0.051	24.0
	guineense						0			
21	Delonix regia	18.70	1.50	0.021	38.40	1.86	2272.3 375-385	4.75	0.039	24.0
							0			
22	Newboudia laevis	18.80	1.50	0.021	34.80	1.77	2272.3 380-393	4.73	0.039	27.0
							0			
23	Mansonia	13.20	9.00	0.015	35.70	1.78	13589. 361-377	5.52	0.054	21.0
	altissima						00			
24	Isoberlina	12.90	0.50	0.014	35.59	1.66	759.30 371-383	5.07	0.058	26.0
	tomensosa									
25	Alstonia	14.40	1.00	0.016	37.25	1.72	1513.0 364-376	6.09	0.051	28.0
	congensis						0			
26	Ficus platyphylia	16.60	22.00	0.019	36.50	1.86	33209.0 378-396	5.85	0.043	21.0
							0			
27	Anogeissus	13.80	6.00	0.016	38.40	1.78	9057.00 380-391	6.51	0.051	25.5
	eiocarpus									

28	Naulea popeguinii	13.80	1.50	0.016	36.25	1.76	2272.30	371-380	4.53	0.051	25.0
29	Vitex doniana	16.30	3.50	0.018	34.78	1.58	5291.30	365-376	6.25	0.046	24.0
30	Triplochiton	13.40	3.90	0.015	36.80	1.68	5894.00	382-394	6.37	0.054	27.0
	Scleroxylon										
31	Khaya senegalensis	14.40	1.20	0.016	35.60	1.84	182.00	370-392	4.27	0.051	27.0
32	Tectona grandis	10.80	6.00	0.012	37.54	1.72	9057.00	360-381	6.51		28.5
33	Irvingia	14.50	8.00	0.016	35.35	1.88	12076.0	380-391	6.0	0.051	24.0
	gabonensis						0				
34	Terminatta Superba	14.40	4.70	0.016	34.75	1.54	7098.00	371-374	5.30	0.051	25.5
35	Pycanantus angolensis	14.50	3.30	0.016	34.65	1.76	4989.90	374-381	4.26	0.051	25.5
36	Gmelina arborea	18.60	0.50	0.020	39.20	1.65	759.30	368-380	5.31	0.041	21.0
37	Lonchocarpus	15.6	7.00	0.018	40.50	1.78	10570	372-384	6.55	0.046	24.0
	griffonianus										
38	Ceiba petandra	9.20	5.50	0.010	38.60	1.90	8310.3	364-379	6.70	0.081	21.0
39	Bombax	12.60	4.50	0.014	36.65	1.92	6797.30	378-386	6.45	0.058	28.0
	buonopozense										
40	Mangifera indica	13.70	1.00	0.015	35.34	1.86	1513.00	368-375	6.65	0.054	26.0
41	Xylopia aethiopica	14.10	5.00	0.016	35.78	1.64	7551.00	380-394	5.31	0.051	26.0
42	Khaya ivorensis	13.60	6.10	0.015	39.25	1.86	9213.4	364-379	6.54	0.054	27.0
43	Oncoba spinosa	13.90	3.50	0.016	36.46	1.80	5291.30	362-374	5.45	0.051	27.0
44	Anlhodesta	14.70	20.00	0.017	35.70	1.66	30190.0	376-386	6.28	0.048	28.5
	dejenalensis						0				
45	Chlorophora	14.50	15.00	0.016	37.59	1.70	22646.0	366-380	6.25	0.051	28.5
	excelsa						0				
46	Hannoa	14.60	5.00	0.016	38.67	1.81	7551.00	385-390	5.85	0.051	24.0

	klaineana										
47	Annoa senegalensis	14.70	10.00	0.017	34.58	1.86	15095.0 0	365-380	6.55	0.048	24.0
48	.Manikara obovata	13.90	5.60	0.016	34.80	1.75	8460.80	376-386	4.29	0.051	25.5
49	Nauclea diderichii	15.60	1.50	0.018	40.74	1.93	2272.30	370-384	5.60	0.046	21.0
50	Daniellia olivera	12.60	3.50	0.014	37.57	1.70	5291.30	366-382	4.53	0.058	26.0
	% detected		100	100	100	100			100		
		100					100	100		100	100
	Range	9.20- 34.40 (Ceiba <i>Petandra</i> , <i>Tetraplur</i>	0.50.00- 33.00 (Anarcad um occidenta le, Ceita zenkeri)	0.01-0.04 (Upia, tetraplura tetrapperia)	33.78-40.74 (Pteracarpus soyouxi, Naulea diderichii)	1.54-1.98 (Pycananthus angolensis, Bragistagia nigeria)	182.00- 105665.00 (KhIaya senIagalen sis, NaIulea diderrichii	360-394 (Terminila ia superba, Triplochit on scloro xylon)	4.10-6.72 (Azadirachta indica, Pteracarpus soyouxi)	0.021-0.08 (Tetraplura <i>tetrapera</i> ), <i>Ceiba</i> petandra)	21.0- 28.5 (Albuzi a ferruge rua, Canari

## table 4.5b

Summary of multiple comparisons for Proximate analysis

Compared Proximates	Mean difference	Leader	Rank
Moisture content Vs Ash content	7.8140	Moisture content	3
" " Specific gravity	15.2710		
" " Crude fibre	-21.4352		
" " Fibre length	13.5134		
,, ,, Ph	9.7690		
" " Porosity	15.2414		
"", "FSP	-10.1700		
Ash content Vs Moisture content	-7.8140		
,, ,, Specific gravity	7.4570		
,, ,, Crude fibre	-29.2492		
" " Fibre length	5.6994		
,, ,, Ph	1.9550	Ash content	4
" " Porosity	7.4274		
,, ,, FSP	-17.9840		
Specific gravity Vs Specific gravity	-15.2710		
,, ,, Ash content	-7.44570		
" " Crude fibre	-36.7062		
" " Fibre length	-1.7576	Fibre length	6
,, ,, Ph	-5.5020		
,, ,, FSP	-25.4410		
Crude fibreVs Moisture content	21.4352		
" " Ash content	29.2492		
" " Specific gravity	36.7062		
" " Fibre length	34.9486		
" " Ph	31.2042		
" " Porosity	36.6766		
,, ,, FSP	11.2652	Crude fibre	1
Fibre length Vs Moisture content	-13.5134		
" " Ash content	-5.6994		
,, ,, Specific gravity	1.7576		
" " Crude fibre	-34.9486		
,, ,, Ph	-3.7444		
,, ,, Porosity	1.7280	Fibre length	7
,, ,, FSP	-23.6834		
PhVs Moisture content	-9.7690		
" " Ash content	-1.9550	Ash content	4
" " Specific gravity	5.5020		
" " Crude fibre	-31.2042		
" " Fibre length	3.7444		
,, ,, Porosity	5.4724		
" " FSP	-19.9390		
Porosity Vs Moisture content	-15.2414		
,, Ash content	-7.4274		
,, ,, Crude fibre	-36.6766		
" " Fibre length	-1.7280	Fibre length	7
,, ,, Ph	-5.4724		

	,,	" FSP	-25.4114		
	FSP	Vs Moisture content	10.1700	FSP	2
,,	,,	Ash content	17.9840		
,,	,,	Specific gravity	25.4410		
"	,,	Crude fibre	-11.2652		
,,	,,	Fibre length	23.6834		
,,	,,	Ph	19.9390		
,,	,,	Porosity	25.4114		

FSP = Fibre Saturation Point

#### **4.10** The physical properties of wood

### **4.10.1** results of the moisture content of the wood samples

From the result of the moisture content of the fifty timbers studied the percentage of moisture content ranged between 9.20 - 34.40% in the wood samples. According to William and Anton (1999) the maximum possible water content in a green wood varies from 26.7% at specific gravity of 0.03 and 44% at specific gravity of 0.90 Gerhards (1982) and USDA (1999) stated that the wood strength is related to the amount of water content in the wood fibre cell wall. Wood gains and loses moisture as change occurs in the temperature and humidity of the surrounding air. Decrease in moisture content of a wood affects the weight dimension and strength of the wood and as well affects both the physical and mechanical properties of wood, depending on whether the moisture content, is above or below the FSP (Table 4.5b .From our result in Table 41.5 and figure 4.10 it is clear that 18(Tetraplura terapera) has moisture content higher than its fsp. 34.23% while the other forty nine Nigerian timbers have values lower than their fsp. 23% which means that the timber whose moisture content value was above its FSP will have both physical and mechanical properly unaffected including wood strength and long service life, while those with lower fibre saturation point will have great changes in their physical and mechanical properties as low fibre saturation point will have great change in wood strength and as such will also affect durability and low service woods with low moisture content showed that the woods do not need to be dried before storage because the low moisture does not encourage microbial growth. The water in wood is either held within walls by bonding forces (hydrogen bonding) between water and cellulose molecule (bound water) or contained in the cavities and not held by these forces (free water). The equilibrium moisture content (EMC) of wood is attained when there is a balance of the amount of bound water it contains with that of water in the surrounding atmosphere. Due to the need for water as part of the photosynthesis and growth process, wood in growing trees contains a considerable amount of water commonly called sap. The percentage moisture content of the fifty Nigerian timbers ranged from 9.20 -34.40%. Majority of the wood have moisture content lower than their fibre saturation point indicating that their physical and mechanical properties will vary as the percentage moisture content changes. The timber with moisture content higher than fibre saturation point will have its physical and mechanical properties remain constant. The low moisture contents suggests that the woods do not need to be dried before storage because the low moisture does not encourage growth. Previous studies have shown that the maximum possible

water content in a wood varies from 26.7% at specific gravity of 0.03 and 44% at specific gravity of 0.90, Thus our results did not depart much from this report. The moisture content at which the cell carvities are free from water is known as the fiber saturation point. Moisture content is a major factor in the processing of wood because it influences all physical and mechanical properties and durability and performance during use. It is defined as the ratio of the mass of water contained in the wood to the mass of the same sample of dry wood. Shrinkage occurs when wood loses moisture below the fibre saturation point.

## Table 4.5b

Compared Proximates	Mean difference	Leader	Rank
Moisture content Vs Ash content	7.8140	Moisture content	3
Specific gravity	15.2710		-
Crude fibre	-21.4352		
Fibre length	13.5134		
	9.7690		
	15.2414		
" " FSP	-10.1700		
Ash content Vs Moisture content	-7.8140		
,, ,, Specific gravity	7.4570		
,, ,, Crude fibre	-29.2492		
" " Fibre length	5.6994		
,, ,, Ph	1.9550	Ash content	4
,, ,, Porosity	7.4274		
,, ,, FSP	-17.9840		
Specific gravity Vs Specific gravity	-15.2710		
,, Ash content	-7.44570		
" " Crude fibre	-36.7062		
" " Fibre length	-1.7576	Fibre length	6
,, ,, Ph	-5.5020		
,, ,, FSP	-25.4410		
Crude fibreVs Moisture content	21.4352		
" " Ash content	29.2492		
" " Specific gravity	36.7062		
" " Fibre length	34.9486		
" " Ph	31.2042		
" " Porosity	36.6766		
,, ,, FSP	11.2652	Crude fibre	1
Fibre length Vs Moisture content	-13.5134		
" " Ash content	-5.6994		
" " Specific gravity	1.7576		
" " Crude fibre	-34.9486		
,, ,, Ph	-3.7444		
,, ,, Porosity	1.7280	Fibre length	7
", ", FSP	-23.6834		
PhVs Moisture content	-9.7690		
,, ,, Ash content	-1.9550	Ash content	4
,, ,, Specific gravity	5.5020		
" " Crude fibre	-31.2042		
,, ,, Fibre length	3.7444		
,, ,, Porosity	5.4724		
,, ,, FSP	-19.9390		
Porosity Vs Moisture content	-15.2414		
,, ,, Ash content	-7.4274		
,, ,, Crude fibre	-36.6766		
,, ,, Fibre length	-1.7280	Fibre length	7
,, ,, Ph	-5.4724		

Summary of multiple comparisons for Proximate analysis

	,,	,, FSP	-25.4114		
	FSP	Vs Moisture content	10.1700	FSP	2
,,	,,	Ash content	17.9840		
,,	,,	Specific gravity	25.4410		
,,	,,	Crude fibre	-11.2652		
,,	,,	Fibre length	23.6834		
,,	,,	Ph	19.9390		
,,	,,	Porosity	25.4114		

FSP = Fibre Saturation Point



Figure 4.10: Moisture content of Wood samples

#### 4.10.2 Result of the percentage ash content of wood samples

From the percentage ash content result in Table 4.5 and figure 4.11, it showed that the ash content of the fifty tropical timber (Nigeria) ranged between 0.50 % to 70.00 %. 10(Naulea diderrichii) has the highest percentage ash content of 34.00 % followed by 8(Ceitis zenkeri 33.50 %), 26(Ficus elastica 22.00 %) and 44 (Anlhodesta dejenalensis 20.00 %) while 11 (Anacardium occidentale) 24 (Isoberlina tomensosa) and 36 (Gmelina arborea) have the lowest percentage ash content of 0.050 %, others have 18 (Tetraplura terapera 18.60 °/o) 5(Lophura lanceolata 10.5 %), 45 (Chlorophora excelsa 15.00 %), and 47 (Annoa senegalensis 10.00 %). Ash content values of most wood were within 0.50 % - 9.60 %. The result of this research showed that the ash content values of some of the wood species from the experiment such as 2 (Hamoa klaineana 5.30 %), 12 (Irvingia gabonensis 5.00 %) 38 (Ceiba petandra 5.50 %), 41 (Xylopia aethiopica 5.00 %) 46 (Garcinia gnetrides 5.00 %), 48 (Manikara obovata 5.60 %), 34 (Terminatlia superba 4.70 %) and 39 (Bombax buonopozense 4.50 %) are similar to the experimental values of seed ash content by Compaore et al., (2011) whose ash content value was 4.98 % and the values of some wood species such as 14 (Azadirachta indica 1.50 %), 16 (Hevea brasiliensis 1.00 %), 20 (Dialum guineensee 1.50 %), 21 (Delonix regia 1.50 %), 22 (Newboudia laevis 1.50 %), 25 (Alstonia congensis 1.00 %), 28 (Naulea popeguinii 1.50 %), 31 (Khaya senegalensis 1.20 %), 40 (Mangifera indica 1.00 %), 49 (Naulea latifolia 1.50 %), 11 (Anacardium occidentale 0.50 %), 24 (Isoberlina tomensosa 0.50 %) and 36 (Gmelina arborea 0.50 %) are similar to the experimental values of seed ash content by Lohlum at al., (2010) whose value was 1.45 % and by Adesuyi et al., (2011) whose value was 0.49 %. Thus, the ash content values for both wood and seed of the plant may be similar according to the experiments on the seed of the plant. Woods with low percentage ash content have less/low mineral content present in the tree. With exception of 10 (Naulea diderrichii 34.00 %) 18 (Tetraplura terapera 18.60 %), 8 (Ceitis zenkeri 33.50 %), 26 (Ficus elastica 22,00 %) and 44 (Anlhodesta dejenalensis 20.00 %), the rest of the wood species have low ash content. Wood ash has been employed into many fields such as health, agriculture - to enrish compost, block garden pestes, melt ice, makes soap, shine silver.

While woods with low percentage ash content have low mineral content present in the wood. Woods that contained below 2.50% ash content have low ash while wood that contained above 2.50% have high content. The ash content of the majority of the timber were within the pulpable standard (1-8%). High ash content is of great economic importance (ash for fillers, for soap, for

drugs, for minerals). Wood ash is the inorganic residue left after the combustion of wood. The ash content recorded in this study is consistent with literature (Fergel and Wegener,1984 who reported that wood grown in the tropics contains more ash than wood grown in the temperate. This is attributed to the type of climate (Temperate 0.1 - 1.0 %, Tropic up to 5 %). The ash content of wood is made up of inorganic minerals primarily calcium, potassium and magnesium.(see table 4.5b).



Figure 4.11: Ash content of Wood samples

## **4.10.3** Results of the specific gravity content of the wood samples

Specific gravity of wood is the density of wood relative to the density of water. It is used as a basis to standardize comparism among species and products. To reduce confusion from varying moisture content, specific gravity of wood is based on oven-dry weight of the wood (David et al., 1999). Thus specific gravity is an excellent index of the amount of wood substance contained in a piece of wood, it is a good index of mechanical properties as long as the wood is clear, straight, grained and free from defects. Specific gravity values also reflect the presence of gums, resins and extractives, which contribute little to mechanical properties (David et al., 1999). The specific gravity results of Table 4.5 and figure 4.12 showed that some woods have high specific gravity while others have low. According to Panshin and Dezeeuw (a) (1964) increase in specific gravity affects the strength of the wood. As specific gravity increases, strength physical and mechanical properties of wood increase, while those with low specific gravity will have properties decrease because internal stresses are distributed among more molecular material. Thus it can be deduced that wood with high specific gravity has high wood strength and as such their physical and mechanical properties will not be affected. Wood with low specific gravity has low wood strength and their physical and mechanical properties will be affected because of decrease in the wood strength. The results of the specific gravity ranged from 0.010 - 0.039. High density generally means harder, stiffer and stronger, but this is not desirable. It is sometimes more important for timber to be light weight and easy to process and manufactured into a wide range of products. Specific gravity is the density of a substance relative to the density of water and is sometimes known as relative density or basic density.



Figure 4.12: Specific gravity of Wood samples

#### 4.10.4 Results of the percentage crude fibre contents of the wood

### Samples

The result of the percentage crude fibre content of the wood sample in Table 4.5 and Fig. 4.13 below showed that the percentage crude fibre content of the wood samples range from 33. 78-40.74 %. The percentage crude fibre and fibre length indicated that the 50 tropical timbers /wood were suitable for pulp making and papers. The fibre length/width also indicated that the 50 tropical woods gave good quality pulps for both raft and fine papers respectively. It can now be deduced that the percentage fibre content of the wood is very high and as such will be utilized in both textile and paper industries. Crude fibre indicates the level of indigestible component of wood. The low crude fibre content shows that the wood has high nutritional value AOAC,(1984).

The result of the percentage crude fibre content of the wood sample in Table 4.5 and figure 4.13 showed that 49 (*Naulea diderichii*) has the highest crude fibre content of 40.74 % followed by 17 (*Birterie fistulosa 40.20 %*) and 16 (*Hevea brasiliensis* 40.12 %), while 3 (*Pteracarpus soyouxi*) has the lowest crude fibre content of 33.78 %. Most of the wood species have their percentage crude fibre content within 33.78 – 39.25 %. Thus the crude fibre values of the fifty Nigerian timbers studied are not similar to the experimental values of seedy crude fibre by Lohlum *et al.* (2010), whose value was 8.43 %, Compaore *et al.* (2011), whose value was 4.70 %, and Adesuyi *et al.*, (201 1) whose value was 1.23 %. Thus crude fibre was higher than the value of the seed crude fibre by Ajiwe and Nnabuenyi (2011) hence they are suitable raw material for the paper industry. Fibre is a class of material that have continous filament, are discrete elongated piece, similar to lengths of thread. They are very important for holding tissues together.

The amount of crude fibre in any material gives the indication of the quantity of food material in terms of starch. The higher the crude fibre value, the lower the quantity of starch.



Figure 4.13: Crude Fiber content of Wood samples

## 4.10.5 **Results of the fibre lengths of the woods**

Result of fibre length ranged from 1.54 mm - 1.98 mm indicating that the fibre length of the fifty timbers gave good quality pulps for both kraft and fine papers (fig. 4.14). Two most important properties of any paper making cellulosic raw material are the cellulose fibre it has and how long the fibres are.



Figure 4.14: Fiber length content of Wood samples

### 4.10.6 Result of thermal conductivity

Table 4.5 and figure 4.15 show the results of thermal conductivity of tropical timbers. The thermal conductivity of the woods ranged between 182.00-105665.00 um.h/tm. The tropical timber Khaya senegalensis has the least thermal conductivity of 182.00 mm.h/tm while the tropical timber Naulea diderrichii has the highest thermal conductivity. From the results, it was observed that there is no steady increase in thermal conductivities of these tropical timbers as their specific gravity (density) increases. The values fluctuates, but from literature heavy woods conduct heat more rapidly than light porous ones (Desch et al., 1981). The fluctuation could be attributed to the following factors: The transmission or conduction of heat depends on two factors (a) the specific conductivity (b) the specific heat of the intervening materials. Wood is a cellular substance in the dry state, the cell cavity are filled with air which is one of the poorest conductor known. The cellular structure of wood also partly explains why heat is conducted about two or three times as rapidly along, compared with across the grain (Desch et al., 1981). However, significant variations in conductivity do exist. These variations in thermal conductivity can be related to variations in gram orientation, temperature and moisture content. Strength and stiffness decrease when wood is heated and increase when cooled. The temperature effect is immediate and, for the most part reversible for short heating durations. However, if wood is exposed to elevated temperature for an extended time, strength is permanently reduced because of wood substance degradation and a corresponding loss in weight. The magnitude of these permanent effects depends on moisture content, heating medium, temperature, exposure period to temperature above 650°C. Thermal conductivity is important to wood processing because heating whether for drying, curing, pressing or conditioning is an integral step. It is a measure of the rate of heat flow in response to its temperature gradient. It depends on the grain orientation.



Figure 4.15: Thermal Conductivity of Wood samples

### **4.10.7 Results of the charring temperature of the wood**

### Samples

Wood is a thermally degradable and combustible material. As wood reaches elevated temperatures, the different chemical components undergo the thermal degradation that affects their performance. The extent of the changes depends on the temperature level and length of time under exposure conditions. Permanent reduction in strength can occur at temperature > 65 °C with the reduction depending on the temperature, pH of wood, moisture content, heating medium, exposure period and species. Strength degradation is likely to be due to polymerization reaction involving no significant carbohydrate weight loss (White and Dietenberger, 2001; Levan, 1989). At 100 °C, the chemical bonds comes to break and are manifested as carbohydrate and lignin weight losses of various types that increase with the temperature (wood pyrolysis). Between 100 °C and 200 °C, wood becomes dehydrated and generated water and other non-combustible gases and liquids, including CO<sub>2</sub>, formic acid, acetic acid, citric acid and water. With prolonged exposures at higher temperatures, wood become charred. Exothermic oxidation reaction can occur because ambient gas can diffuse into it and react with the developing porous char residue (White and Dietenberger, 2001). From 200°C to 300°C, some wood components begin to undergo significant pyrolysis. The hemicelluloses and lignin component are pyrolyzed in the range 200 °C - 300 °C and 225 °C -450 °C respectively. Much of the acetic acid from wood pyrolysis ii attributed to deacetylation of hemicelluloses (100 °C to 450 °C) because the vigorous production of flammable and significant dcpolymerization of cellulose begins in the range of 300 °C – 450 °C. Also around 300 % aliphatic side chains start splitting off from the rings in the lignin. Finally, the carbon - carbon linkages between lignin structural units is cleaved from 370 °C to 400 °C (White and Dietenberger, 2001). Comparing the above literature with our result in table 4.5 and figure 4.16 we deduce that woods that charred below 65 °C have faster rate of charring. While those that charred at 100 °C have the chemical bonds between wood particles broken and those charred above 100°C the wood become radiated and generates water vapour and other noncombustible gases including CO<sub>2</sub>, furmic acid, and acid water. Since wood charring is the primary factor that determines the load-carrying capacity of structural wood timbers in a fire, therefore wood with high rate of charring temperature will have high ability of load carrying capacity, than wood with low charing rate. During pyrolysis at a low heating rate, there is less distruption of the carbon-to-carbon residues which condense into char. The fifty tropical timbers have high charring temperature which indicated that they cannot be easik destroyed. The charring temperature was determined in all the samples.


Figure 4.16: Charring Temperature of Wood samples

#### 4.10.8 Result of the wood ph

pH is a negative decimal logarithm of the hydrogen ion activity or concentration in a solution. It is a measure of the acidity or basicity of an aqueous solution. Solutions with pH value between 0 and 6.5 are said to be acidic, solution with pH value from 6.5-7.5 are neutral while solution with pH value from 7.6-14 are basic or alkaline.

Wood is generally acidic and pH values as low as 3.0 have been found in the heartwood of oak; however, most trees have a heartwood pH of 4.5-5.5 (Franco and Jon, 2009). Acidity in wood is caused by free acetic acid which is found in wood. Cellulose which is a principal constituent of wood is a polysaccharide and contains mildly basic hydroxyl radicals, a proportion of which is combined with acetic acid radicals (acetylated) to form ester (organic salt) groups. These groups combine with water (hydrolysed) to give free hydrolysed radicals and acetic acid. This process causes the moisture in the wood to be acidic always (Franco and Jon, 2009). Due to acetic acid content present in wood, wood is a corrosive substance by nature and as such wood can cause of metal nearby but not corrosion actually in contact

Small quantity of formic acid, propionic acid, and pyric acid present in wood increase the wood acidity but their effect can be neglected in comparison with those of acetic acid. Although, acetic acid is volatile and can easily escape, yet the rate of emission of acetic acid depends on the wood species and a wood of lower acetyl content liberate acetic acid faster under given conditions than another wood of higher content. The presence of sulphate and chloride radicals in wood augument the corrosive action of the acetic acid. From literature of work done on woods it showed that the pH values of woods ranged between 4.10-8.80 but these pН values depend on the temperature, moisture content and wood species (TAPPI,1983). From our pH results in Table .5 and Figure 4.17, the pH result showed that the pH values of the wood samples ranged between 4.10-6.72 with 3(pteracarpus soyouxi) having the highest pH value of 6.72 while 14 (Azadirachta indica has the lowest pH value of 4.10. The bulk of them tend to be slightly acidic. Also from Table 4.5 and Figure 4.17 it was observed that the woods have moderate moisture content range of 9.20-34.40% which in turn leads to most woods having a weak acid pH values. The pH values of the studied timbers were inconsistent to that reported by Franco and Jon, (2009) that wood is generally acidic. The acidity of woods is attributed to samples over laid with salt precipitations. From available literature (Grunnar, 2008) the average pH in aqueous extracts of vasa wood and fresh oak wood was approximately 4.0 and from our analysis, the average pH was close to that of the literature.



Figure 4.17: Result of pH of Wood samples

#### **4.10.9** Results of the porosity index of the wood

Table 4.5 and figure 4.18 showed the result of the porosity index of the fifty Nigerian timbers. The results indicated the presence of air spaces in the woods. Porosity or void fraction is a measure of the void "empty" spaces in a material, and is a fraction of the volume of voids over total volume. Pore space can be filled with either water or air. Smaller pores tend to be filled with water. Small amount of water that filled pores is referred to as capillary porosity while large pores are typically filled with air, these air-filled pores are referred to as non-capillary porosity. Hard woods have cells of relatively large diameter known as vessels or pores. These cells form the main conduits in the movement of sap and water up the stem and provide channels for delivery of food to the living cells, particularly at the cambium, Soft woods do not contain vessels for conducting sap longitudinary in the tree; this function is performed by the tracheids (William and Anton, 1999). Wood porosity also affects the mechanical properties of wood, thus enhances conducts of water and nutrient vertically in wood, which are present in hard wood. Thus wood with large pore spaces can be said to be soft word while wood with small pore spaces can be said to be hard wood (William and Anton 1999). But from the results in Table 4.5 and Figure 4.18, it was observed that most wood species with higher pore spaces are softwood while those of lower pore spaces are hardwood. Porosity or permeability is a measure of the flow characteristics of a liquid or gas through wood as a result of the total pressure gradient. The porosity values of this study ranged from 0.021-0.081.



Figure 4.18: Porosity of Wood samples

#### **4.10.10** Results of the fibre saturation point of the wood samples

Water exists in wood either as bound water (in the cell wall) or free water (in the cell cavity). As bound water, it is bonded (via secondary or hydrogen bonds) within the wood cell walls. As free water, it is simply present in the cell cavity (Arntzen, 1994). Moisture in wood moves within the wood as liquid or vapour through several types of passage ways based on the nature of the driving force, such as pressure or moisture gradient and variations in wood structure (Langris and Walker, 1993). These pathways consist of cavities of the vessels, pit chamber and their pit membrane openings, intercellular cells and transitory cell wall passageways. Movement of water takes place in the passage ways in any direction, longitudinally in the cell until it reaches the final drying surface of the wood (Langris and Walker, 1993). When wood, dries most free water separates at a faster rate than bound water because of feasibility and the absence of secondary bonding. The moisture content at which the cell walls are saturated and the cell cavities are free from water is called the fibre saturation point (FSP) and fibre saturation point usually varies between 21 and 28% (Amtzen, 1994). Wood gains and loses moisture as change occurs in the temperature and humidity of the surrounding air. Decrease in moisture content of a wood affects the weight dimensions and strength of the wood. And as well affects both the physical and mechanical properties of wood, depending on whether the moisture content is above or below the FSP. (Table 4.5b) If the moisture content is above the FSP, the physical and mechanical properties of wood will remain constant but if it is below FSP, the physical and mechanical properties will change as the percentage moisture content changes. According to Desch and Dinwoodie, (1996) decrease of water below the Fibre Saturation Point increases the wood strength except for impact bending strength, and increases the electrical receptivity of the wood. This is because below FSP all moisture is bonded to the cell wall which act like sponges, swelling when water is added and shrinking when wood is dried. Decrease in moisture content can also lead to wood shrinkage although moisture content of wood is not always constant as it can change while wood is in use. Moisture content of in service timber or lumber will change with environmental condition. The FSP varies from different species of wood that is typically around 23-30%. The fibre saturation point (fig. 4.19) recorded in this study is in the same range with that recorded in literature typically around 23-30% (Arntzen, 1994, and Stamm, 1927).



Figure 4.19: Result of Fiber Saturation Point of Wood samples

#### 4.11 Results of the analysis of colour

From literature, wood colour aids in the identification of types of wood (hardwood and soft wood). Hardwoods come with a variety of colours and shades that often allow immediate and unmistakable recognition. Hardwood colours can range from pure white through red to deep brown or even black white through red to deep brown or even black while softwood are pailer in colour ranging from white to yellow, sometimes tinged with colour, although both hardwoods and soft wood colours darken when exposed to light. Following the above literature, our wood samples are classified into hard wood and softwood as shown in Table 4.6.

## Table colour characteristics are shown in Table 4.6

	Botanical Name	Colour	Classification
1.	Brachystegla Nigeria	Cream	Soft
2.	liamoa klaineana	Carton	Hard
3.	Pteracarpus soyouxi	Brown	Hard
4	Garcinia kola	Light yellow	Soft
5	Lophura lanceolata	Cream	Soft
6	Albuzia /zygia	Chocolate	Hard
7	Brachystigia eurecomya	Carton	Soft
8	Ceitis zenkeri	White	Soft
9	Cola gigantia	Khaki	Hard
10	Naulea diderrichii	Brown	Hard
11	Anarcardum occidentate	Carton	Soft
12	Iruingia gabanonesis	Cream	Soft
13	Aibizia ferruginea	Orange	Soft
14	Azadirachta indica	Khaki	Hard
15	Canariun schwafurihii	Light red	Hard
16	Hevea brasiliensis	Com silk	Soft
17	Barteria fistulosa	Cream	Soft
18	Tetraplura turapera	Milk	Soft
19	Pyeftanthus angolensis	Brown	Hard
20	Diatum guinease	Light yellow	Soft
21	Dclinux regia	Golden	Soft
22	Newhoitdiu Iaevis	Corn silk	Soft
23	Mansonia altissima	Khaki	Soft
24	Isoberlina tomensosa	Light red	Hard
25	Alstonia congensis	Brown	Hard
26	Ficus elastic	Light yellow	Soft
27	Anogeissus eiocapus	Deep brown/red	Hard

28	Naulea popeguinii	Orange	Soft
29	Vitex doniana	Com silk	Soft
30	Triplochiton scleroxylon	Carton	Hard
31	Khaya senegalensis	Golden	Soft
32	Tectona grandis	Cream	Soft
33	Irvingia grandifolio	Brown	Hard
34	Terminatlia superb	Pale while	Soft
35	Baphia nitida	Khaki	Soft
36	Gmelina arborea	Cream	Soft
37	Lonchoca pus griffonianus	Yellow	Soft
38	Ceiba petandra	Com silk	Soft
39	Bambax buonopozense	Brown	Hard
40	Mangifera indica	Brown	Hard
41	Xylopia aethiopica	Brown	Hard
42	Khaya ivorensis/Khayagr	Light red	Hard
43	Oncoba spinossa	White	Hard
44	Anlhodesta dejenalensis	Wheat	Hard
45	Chlorophora excels	Brown	Hard
46	Garania gnetrides	White	Hard
47	Annoa senegalensis	Red	Hard
48	Manikara obovata	Carton	Hard
49	Naulea diderichii	Khaki	Hard
50	Daniella Olivera	Cream	Soft

	Botanical Name	Coldwater 20°C	Hot water 100°C	Ether	1% NaOH
1.	Brachystegla Nigeria	1.16	2.27	0.34	10.03
2.	Hamoa klaineana	2.10	5.60	0.75	13.01
3.	Pteracarpus soyouxi	4.28	1130	1.93	13.34
4	Garcinia kola	10.60	14.20	2.06	23.03
5	Lophura lanceolata	1.50	3.45	1.00	10.83
6	Albuzia /zygia	1.54	1.99	1.80	21.83
7	Brachystigia eurecomya	2.35	4.41	2.07	20.10
8	Ceitis zenkeri	4.28	6.20	1.03	20.01
9	Cola gigantia	2.97	4.20	1.39	20.20
10	Naulea diderrichii	3.19	5.45	0.90	21.81
11	Anarcardum occidentate	3.31	6.20	0.77	20,08
12	Iruingia gabanonesis	9.12	12.15	1.76	37.13
13	Aibizia ferruginea	7.06	10.60	1.76	14.21
14	Azadirachta indica	5.05	8.15	1.71	19.18
15	Canarium schwafurihii	2.12	4.10	0.56	28.11
16	Hevea brasilensis	6.55	8.25	0.33	28.60
17	Barteria fistulosa	6.45	9.45	0.63	22.06
18	Tetraplura terapera	3.27	5.22	0.71	21,10
19	Pyenanthus angolensis	5.26	7.20	1.24	17.81
20	Dialum guinease	2.18	3.40	1.22	25.12
21	Delinox regia	8.29	11.20	0.74	13.72
22	Newboudia laevis	2.01	3.50	1.74	27.21
23	Mansonia altissima	8.07	10.71	1.31	13.85
24	Isoberlina tomensosa	2.22	4.51	0.36	38.12
25	Alstonia congensis	0.50	6.52	1.46	10.03
26	Ficus elastic	1.10	3.33	0.45	13.01
27	Anogeissus eiocapus	2.00	4.25	0.72	1334

Results of solubility tests and their graphical representation are shown below Table 4.7 Results of Solubility Test %

28	Naulea popegi	uinii	4.20	6.30	0.3	34	28.85
29	Vitex doniana		10.25	14.25	2.1	15	10,83
30	Triplochiton se	cleroxylon	1.40	2.60	0.1	12	11.83
31	Khaya senegal	ensis	1.50	3.56	0.2	26	20.10
32	Tectona grand	is	2.25	4.54	0.3	35	22.21
33	Irvingia grand	ifolio	4.22	630	1.3	35	20.20
34	Terminatlia su	perb	2.64	3.99	0.6	54	21.01
35	Baphia nitida		3.19	5.20	1.0	)5	20.08
36	Gmelina arbor	rea	3.30	5.46	0.2	20	27.13
37	Lonchocarpus		9.01	12.36	2.1	10	14.21
	griffonianus						
38	Ceiba petandro	a	7.00	10.15	2.2	21	19.18
39	Bombax buond	pozense	5.02	8.20	1.3	32	28.11
40	Mangifera indi	ica	2.11	4.10	0.2	26	28.60
41	Xylopia aethio	pica	6.35	9.30	1.4	48	22.04
42	Khaya ivorens	is/Khayagr	6.40	9.35	2.2	25	21.13
43	Oncoba spinos	'S	3.19	6.25	1.3	38	15.81
44	Anlhodesta dej	ienalensis	5.20	8.10	1.2	23	23.12
45	Chlorophora e	xcels	2.10	3.40	0.7	72	13.72
46	Garania gnetri	ides	8.10	10.54	1.8	85	27.13
47	Annoa senegal	ensis	2.00	4.20	0.6	52	13.85
48	Manikara obov	vata	8.00	11.30	1.9	<del>)</del> 9	28.12
49	Nauclea dideri	chii	2.20	3.63	0.6	59	20.13
50	Daniella oliver	ra	0.80	10.23	1.7	76	21.07
	Range	(Alstonia c Vites donic	0.05-10.25 cogenesis, ana)	1.99-14.25 (Albuzia zygia, Vites doniana)	0.12-2 (Triplochiton scleroxylon, Khaya ivorensis	2.25 (Bragyst and Alst s) Isoberli	10.03-38.12 gia nigeria onia cogenesis, ina tomensosa)



Figure 4.20: Solubility in cold water of Wood samples



Figure 4.21: Solubility in Hot water of Wood samples



Figure 4.22: Solubility in Ether of Wood samples



Figure 4.23: Solubility in 1% NaOH of Wood samples

#### 4.12 **Result of the wood solubility studies**

The solubilities in cold, hot water and 1 % NaOH of the wood samples enable us to determine the suitable delignification solvent. Solubility values for cold water ranged from 1, 10- 10.60 %, with *Alstonia cogenesis* having the highest solubility value and *Gacinia kola* having the lowest solubility value. Tthat for hot water ranged from 1.99 - 14.25 %, with *Albizia ferrugerua* having the highest solubility value and *Gacinia kola* and *Vites doniana* the lowest. Values for ether ranged from 0.12 - 2.25 % with *Triptochiton sclerosylon* having the highest solubility value and *Khaya ivorensis* having the lowest solubility value. Values for 1 % NaOH ranged from 10.3 - 38.12 % with *Brachystegia nigeria*, *Alstonia cogenesis* having the highest solubility value and *Isoberlina tomensosa* having the lowest solubility value (Figure 4.20 – 4.23). One percent sodium hydroxide is a better solvent for delignification of plant. The solubility values for the four different solvents are lower than that recorded for non-woody plants like *paudau candelabrum* root (30.50%) and leaves (26.75 %) (Akpabio and Enos, 1999). The result from solubility values of this study showed that solubility values in 1 % NaOH is higher than the solubility study of other three solvents. The values are however lower than those reported by Akpabio and Enos, 1999 for non-woody plants.

# The results of chemical characteristics of the Wood samples are shown in Table 4.8 and Fig 4.24-4.28

Botanical .Names Pro	tein value	Acid value	Free Fatly	Saponif	ication Perox	xide	
Iodine							
	(%)	$(g/1000 \text{ cm}^3)$	Acid value	% value (m	ng/g) value	(mg/g)	
1. Brachystegla Nigeria	8.40	9.82	4.23	196.40	8.00	19.70	
2. Hamoa klaineana	9.20	11.30	3.07	102.60	8.67	20.91	
3. Pteracarpus soyouxi	9.00	9.90	5.30	172.75	9.30	17.80	
4. Garcinia kola	8.70	12.30	4.20	132.41	8.10	22.70	
5. Lophura lanceolata	8.80	12.20	3.75	101.95	7.91	20.70	
6. Albzuia zygia	8.60	13.90	4.35	131.21	8.%	21.91	
7. Brachystigia eurecomy	va 9.40	13.70	3,90	125.10	8.91	22.92	
8. Ceitis zenkeri	9.10	12.60	5.26	107.70	9.12	17.32	
9. Cola gigantia	10.00	11.70	3.95	115.30	9.35	18.46	
10. Naulea diderrichii	7.90	9.60	6.15	167.10	7.97	17.96	
11. Anacardum occidente	ele 8.60	13.20	3.39	191.40	7.89	19.33	
12. Iruingia gabanonesis	8.90	11.70	4.25	194.70	9.40	20.91	
13. Aibizia ferruginea	10.20	10.40	5.12	109.12	8.91	21.92	
14. Azadirachta indica	8.30	9.50	3.95	197.25	7.87	20.39	
I5. Canarium schwafurik	<i>iii</i> 8.70	8.60	4.10	192.15	8.91	22.12	
1 6. Hevea brasiliensis	10.50	13.50	4.55	109.45	95.5	20.97	
17. Bacteria fistulusa	7.60	11.60	7.13	116.14	8.91	18.93	
18. Tetraplura terapera	8.30	10.30	4.16	146.10	7.93	17.89	
I9. Pyenanthus angolensi	s 9.30	9.40	3.85	191.65	9.91	16.99	
20. Dialum guineese	9.10	9.80	5.70	164.10	9.81	17.86	

## Table 4.8: Result on chemical characterisation of selected tropical timers oil

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21.Delonix regia	8.70	10.60	3.65	142.15	7.86		19.73
22. Newboudia laevis	11.10	11.20	5.60	193.16	7.98		18.32
23.Mansonia altissima	8.80	10.10	6.10	I95.18	8.19		17.31
24. lsoberlina tomensosa	9.30	12.40	7.12	109.70	9.36		18.47
25. Alstonia congensis	8.90	11.50	5.20	109.80	7.96		19.39
26. Ficus elastic	9.10	10.60	4.40	192.70	8.97		18.30
27. Anogeissus eiocapus	8.20	13.20	4.93	196.40	9.93		17.40
28. Naulea popeguinii	9.10	9.30	3.15	190.05	8.30		16.89
29. Vitex doniana	7.30	10.40	5.23	101.95	S.95		18.39
30. Triplochiton	9.10	11.70	4.45	107.91	9.36		19.32
scleroxylon	,				2.000		
31. Khaya senegalensis		7.60	10.50	3.92	106.82	10.10	19.72
32. Tectona grandis		12.10	10.60	3.67	108.62	9.31	20.99
33. Irvingia grandifolia		9.30	11.10	6.40	191.40	8.38	21.32
34. Terminatlia superb		8.70	9.60	4.72	163.90	7.94	17.39
35. Baphia nitida		8.90	9.40	5.14	194.10	9.47	18.15
36. Gmelina arborea		11.30	11.20	6.07	I09.80	9.39	17.86
37. Lonchocarpus griffonianus	5	7.60	10.70	3.70	107.95	8.90	19.34
38. Ceiba petandra		8.70	13.60	6.16	109.65	8.60	18.39
39. Bombax		10.60	15.00	4.39	167.70	7.95	19.15
40. Mangifera indica		10.80	13.30	4.14	150.62	8.35	19.37
41. Xylopia aethiopica		9.50	8.70	4.32	145.70	9.36	18.72
42. Khayairorensis		7.90	9.70	5.20	151.85	8.79	19.37
43. Oncoba spinosa		9,30	10.30	5.31	163.30	8.67	18.17
44. Anlhodesta dejenalensis		8.60	12.50	5.15	170.96	9.35	17.99
45. Chlorophora excels		8.80	11.40	3.96	191.75	7.91	18.93
46. Garania gnetrides		9.20	12.10	4.31	169.63	9.39	19.37
47. Annoa senegalensis		9.10	13.91	5.91	192.33	8.91	18.32
48. Manikara obovata		8.20	10.99	4.36	173.47	7.34	18.92
49. Naulea laifolia		9.20	11.39	3.91	187.32	8.37	19,12
50. Daniella olivera		7.99	8.40	4.89	169.15	9.12	17.93

#### 4.13 Results of the acidic value of the wood oil

39 (Bombax buonopozense) has the highest acid content of 15.00 g/100ml, followed by

6 (Albuzia zygia 1 3. 90 g/ 100ml), 38(ceiba petandra 13.60g/100ml), 6(Hevea brasiliensis 13.50 g/100ml), 47 (Annoa senegalensis 13.91 g/100ml), 40 (Mangifera indica 13.30 g/100ml), 7 (Bracchyshgia eurecomya 13.70 g/100ml), 11 (Anihodestra dejenalensis 12.50 g/100ml), 24 (Isoberlina tomensosa 12.40/100ml), 4 (Garcania kola 12.30g/100ml), 5 (Lophura lanceolata 12.20g/100ml), 9, 12 and 30(Cola gigantia, irvingia gabanonensis and triplochiton scleroxylon 11.70 g/100ml), 17 (Barteria fistulosa 11.60 g/100ml), 25 (Alstonia congensis 11.50g/100ml), 45 (Chlorophora excelsa 11.40 g/100ml), 49 (Naulea latifolia 11.39 g/100ml), 2 (Hamoa klaineana 11.30 g/100ml), 22. 36 (Navboudia laevis, Gmelina arborea 11. 20 g/100ml), 33 (Irvingia grandifolia 11.10 g/100ml), 48 (Manikara oborata 10.99 g/100ml), 37 (Lonchocarpus griffonianus 10.70 g/100ml), 21, 26, 32, (Delunix regia, ficus elastica and tectona grandis 10.60 g/100ml), 31 (Kyaya senegalensis 10.50 g/100ml), 13 (Albizia ferruginea 10.40 g/100ml), 29 (vitex doniana 10.40 g/100ml), 18 (Retraplura terapera 1030 g/100ml), 43 (Oncoba spinosa 10.30/100ml) and 23(Mansonia altissima 10.10g/100ml), while the lowest acid value was observed in the following species 1 (Brachystegia nigeria 9.82 g/100ml), 3 (Pheracarpus Soyouxi 9.90g/100ml), 10 (Naucler diderichii 9.60 g/100ml), 14 (Azadirachta indica 9.50g/100ml), 19 (Pyencnthus angolensis 9.40 g/100ml), 20 (Dialum guineese 9.80/100ml), 28 (Naulea popeguinii 9.30 g/100ml), 34 (Terminatlia superb 9.60 g/100ml), 35 (Baphia nitida 9.40 g/100ml), 42 (Khaya ivorensis 9.70 g/100ml), 15 (Canarium schwafarihii 8.60 g/100ml), 41 (Xylopiaa ethiopica 8.70 g/100ml) Table 4.8 and Fig. 4.24. Acid value is the number of milligram of potassium hydroxide (KOH) required to neutralize the free fatty acid present in 1g of sample oil. It is also a measure of the amount of free acid present in the oil or fat sample (Bernfield, 1987). The acid values of this study ranged from 8.40 mg/g - 15.00 mg/g. These values are lower than those reported by Agwu, (2006) for *Pachystela brevipes* oil in seed 15.65 mg/g and seed coat 44.80 mg/g. The presence of acid in the oils is not surprising since wood generally contain organic salt which on hydrolysis produce acetic acid. The acidity is attributed to samples overlaid with salt precipitation. The acidic property of the oils indicated that the oils were not so prone to oxidative rancidity or degradation and oils with low acid values are good for human consumption.



Figure 4.24: Acid value of Wood samples

#### 4.14 Free fatty acid content

Free fatty acids are fatty acids that are not tied onto a glycerin molecule. percentage free fatty acids indicate the care and control exercised during processing. It is an indication of fresh oil/fat quality. In well-refined oil, the typical free fatty acid level should be less than 0.05%. Very high levels of FFA (e.g. about 3-4%) (Bernfield,1987) can result in excessive smoking and unsatisfactory flavor. In this study, the free fatty acid ranged from 3.07% in number 2 - 7.13% in number 17. It was observed from our result in Table 4.8 and Fig. 4.25 that free fatty acid of the fifty tropical timbers were high. Aside, from the lignocelluloses, wood consists of a variety of low molecular weight organic compounds called extractives. The wood extractives are fatty acid, resin acids, waxes and terpenes. The extraction of these organic materials from wood provides tall oil, turpentine and rosin (Froouni *et al.*, 2000). From the result of the experiment free fatty acid content was approximately half of the acid value.



Figure 4.25: Free fatty acid content of Wood samples

#### 4.15 Saponification value

From the result of the experiments, saponification value of the fifty Nigerian timbers in Table 4.8 and Fig. 4.26 showed that the saponification value of the woods ranged from 101,95 to 197.25 mg/g. 14(Azadirachta indica) has the highest saponification value of 197.25 mg/g, followed by 1(Brachystegia nigeria 196.40 mg/g), 27 (Anogeisus eiocapus 196.40 mg/g), 23 (Mansonia altissima 195.18 mg/g), 12 (Irvingia gabonensi 194.70 mg/g), 22 (Newboudia laevis 193.16 mg/g), 15 (Canarium schwafurihii 192.15 mg/g), 26 (Ficus elastic 192.70 mg/g), 47 (Annoa senegalensis 192.31 mg/g), 19 (Pyenanthus angolensis 191.65 mg/g), 11 (Anarcardium occidentale 191.40 mg/g), 28 (Naulea popeguinii 190.05 mg/g), 33 (Irvingia grandifolio 191.40 mg/g), 35(Baphia nitida 194.10 mg/g), 45 (Chlorophora excels 191.75 mg/g), while 5 (lophura lanceolata) and 29 lowest saponification value of 101.95 followed by 2 (Hamoa (Vitex doniana) have the klaineana 102.60 mg/g), 8 (Ceitis zenkeri 107.70 mg/g), 13 (Aibizia ferruginea 109.12 mg/g), 16 (Havea brasiliensis 109.45 mg/g), 24 (Isoberlina tomensosa 109.70 mg/g), 25 (Alstonia congensis 109.80 mg/g), 30 (Triplochiton scleroxylon 107.91 mg/g), 31 (Khaya senegalensis 106.82 mg/g), 32 (Tectona glandis 108.62 mg/g), 36 (Gmelina arborea 109.80 mg/g), 37 (Lonchocarpus griffonianus 107.95 mg/g) and 38 (Ceiba petandra 109.65 mg/g). Saponification value of most wood was within 115.30 mg/g - 187.32 mg/g. Saponification value is defined as the number of milligram of KOH required in changing 1g of fat completely to glycerol. The saponification value of some of the tropical timbers fall within the range reported for castor seed oil (175 - 187 mg/g). The value is quite high because there is an inverse relationship between saponification value and weight of fatty acids in the oil. High saponification value is an indication that an oil contains a greater number of fatty acids of low molecular weight and can thus be employed in the soap industry and in the manufacture of lather shaving creams.



Figure 3.26: Saponification value of wood samples

#### 4.16 Result of the peroxide value of the wood samples

The results of the perioxide value of the wood species are as shown in Table 4.8and Fig. 4.27 which showed that the perioxide value of the woods ranged between 7.34 mg/g-10.10 mg/g. (Khaya senegalensis) has the highest perioxide value of 10.10 mg/g seconded by 16 (Havea brasiliesis 9.95), 27(Anogeissus eiocupus 7.93mg/g), 19(Pyenanthus angolensis 9.91 mg/g), 20 (Dialum guineense 9.8 mg/g), 35 (Baphia nitida 9.47mg/g), 46 (Garcinia netrides 9.39 mg/g), I2(Irvigia gabanonensis 9.40 mg/g), 36 (Gmelina arborea 9.39mg/g), 24 (Isoberlina tomensosa 9.36mg/g), 30 (Triplochiton scleroxylon 9.36 mg/g), 41 (Xylopia aehiopica 9.36 mg/g), 44 (Anlhodesta dejenalensis 9.35 mg/g), 32 (Tectona grandis 9.31 mg/g), 3 (Pteracarpus soyouxi 9.30 mg/g),and 9 (Cola gigantia 9.35 mg/g). The lowest peroxide value was observed in 48 (Manikara obovata 7.34 mg/g), periodic value of most of the wood samples was within 7.34 mg/g -8.97 mg/g), The peroxide value of this study is lower than that of citrullus lonatus (18.75mg/g). This could be due to the freshness of the wood oil used for analysis. Fresh oils have shown peroxide values lower than 10 mg/g and oil becomes rancid when peroxide goes up to the range of 20.0 to 40 mg/g (Pearson, 1976). The peroxide value of oils is a measure of the amount of hydroperoxides present in them. Ojeh (1981) reported that oils with high peroxide values are unstable and easily becomes rancid (having a disagreeable odour). The range of values 7.34 mg/g – 10.10 mg/g obtained for the 50 tropical timbers were compared with the international olive oil council (IOOC) and Chemical Abstract Services (CAS) standards for virgin oils (20 meq/kg). The low value obtained for this oil shows that it is not susceptible to oxidation and could be reduced by refining. It can thus be deduced that oil from the fifty tropical timbers would be stored for a longer time without deterioration than oil from Citrullus lonatus.



Figure 4.27: Peroxide value of wood samples

#### **4.17: Result of iodine value of selected tropical wood samples**

The result of the iodine content of the wood in Table 4.8 and Fig. 4.28 showed that the iodine value of the wood samples ranged between 16.89-22.92 mg/g. 7(*Brachystegia eurecomya*) has the highest iodine value of 22.92 mg/g followed by 4 {*Garcinia kola 22.70 mg/g*}, 14 (*Azadirachta indica22.12mg/g*)5(*Lophuralancealata*21.91mg/g), 12(*Irvingia gabanonesis* 21.92

mg/g), 33(Irvingia grandifolio 21.32mg/g), 2(Hamoa klaineana 20.91 mg/g), 11(Anacardium occidentale 20.91 mg/g), 13(Albizia ferruginea 20.39 mg/g), 15(Canarium schwafurihii 20.97mg/g) and 32(Tectona grandis 20.99mg/g). The average iondine value in various wood was observed in 1(Brachystegla nigeria 19.70mg/g), 10(Naulea diderrichii 19.31mg/g), 20(Dialum guineense 19.73 mg/g), 31(Khaya senegalensis 19.72mg/g), 24(Isoberlina tomensosa 19.39mg/g), 30(Triplochiton scleroxylon 19.32mg/g), 37(Lonchocarpus griffonianus 19.34mg/g), 39(Bombax buonopozense 19.15 mg/g), 40 (Mangifera indica 19.37 mg/g), 42 (Khaya ivorensis 19.37 mg/g), 46(Garcinia gnetrides 19.37 mg/g) and 49 (Naulea latifolia 19.12 mg/g). The lowest iodine value was observed in 27 (Anogeissus eiocapus 16.89 mg/g). iodine value of most of the wood samples was within 16.89 mg/g-18.93 mg/g. Iodine value is the number of grams of iodine absorbed by 1.0g of oil. It indicates the unsaturation present in the oil. The range of values of iodine 16. 89 -22.92 mg/g indicated that the oils were non-drying oil and could be used in making alkyd resin, binders in paints, varnish and plasticizers. The oils were vital for use in the soap making. Basically, it should be noted that oils with iodine value 80-100 are non drying oils, 100-200 are semi -drying oils, while above 180 are drying oils. The iodine value of wood samples recorded in this study is lower than that reported by Agwu, (2006) for Pachystella brevipes seeds and seed coat.



Figure 4.28: Iodine value of wood samples

Sample	Botanical Names	% Cellulose	Hemi cellulose (%)	% lignin
1	Brachystegia nigeria	6.66	20.0	33.8
2	Hamoa klaineana	6.66	24.0	7.1
3	Pteracarpus soyouxi	0.53	20.0	14.7
4	Garcinia kola	26.6	28.0	72.2
5	Lophura lanceolata	10.0	30.2	70.5
6	Albizia zygia	36.7	26.0	14.2
7	Brachystegia eurecomya	66.6	32.0	63.2
8	Ceitis zenkeri	26.6	25.0	99.4
9	Cola gigantia	60.0	23.0	14.70
10	Naulea diderrichii	66.6	27.0	13.8
11	Anacardum occidentele	93.3	29.0	25.6
12	Irvingia gabanonesis	93.3	23.0	90.9
13	Aibizia ferruginea	66.6	37.0	70.5
14	Azadirachta indica	13.3	29.0	17.6
15	Canarium schwafurihii	30.0	23.0	11.6
16	Hevea brasiliensis	83.3	20.0	30.5
17	Bacteria fistulusa	133.3	25.0	35.4
18	Tetraplura terapera	13.3	26.0	47.6
19	Pyenanthus angolensis	66.6	30.0	5.6
20	Dialum guineese	93.3	35.0	66.3
21	Delonix regia	63.3	24.0	29.8
22	Newboudia laevis	66.6	29.0	43.5
23	Mansonia altissima	13.3	25.0	85.3
24	Isoberlina tomensosa	30.0	35.0	12.17
25	Alstonia congensis	83.3	20.0	24.3
26	Ficus elastic	40.0	30.0	65.2
27	Anogeissus eiocapus	40.0	24.0	43.0
28	Naulea popeguinii	36.7	20.5	36,1

The Cellulose and Lignin contents of the wood samples are shown in table 4.9 and Figures 4.29-4.31 Table 4.9 Cellulose, Hemi cellulose and Lignin contents

Sampl	e Botanical Names	% Cellulose	Hemi cellulose	e (%)	% lignin
29	Vitex doniana	33.3	27.0	42.0	
30	Triplochiton scleroxylon	36.7	20.0	11.1	
31	Khaya senegalensis	40.0	23.6	59.8	
32	Tectona grandis	73.3	33.5	26.6	
33	Irvingia grandifolio	56.7	24.0	16.7	
34	Terminatlia superba	33.3	30.0	39.8	
35	Baphia nitida	60.0	20.0	90.9	
36	Gmelina arborea	40.0	30.0	62.5	
37	Lonchocarpus griffonianus	60.0	28.0	48.6	
38	Ceiba petandra	46.7	30.0	41.6	
39	Bombax buonopozense	36.7	31.0	23.17	
40	Mangifera indica	13.3	32.0	16.6	
41	Xylopia aethiopica	30.0	28.0	22.0	
42	Khaya ivorensis	36.7	25.0	11.76	
43	Oncoba spinose	63.3	21.8	14.20	
44	Anlhodesta dejenalensis	30.0	26.0	23.0	
45	Chlorophora excelsa	13.3	20.0	14.2	
46	Garania gnetrides	66.6	30.0	17.6	
47	Annoa senegalensis	93.3	30.0	5.63	
48	Manikara obovata	63.3	26.0	12.17	
49	Naulea diderichii	66.6	21.0	11.1	
50	Daniella oliveri	13.3	32.0	39.8	
% dete	cted	100	100		100
Range		0.53- 133.3(Teracarpus soyouxi, Barteria fistulosa)	20.00-37.00( Pteracarpus soyouxi, Albizia ferruginea)		5.6-99.4 (Pyenanthus angolensis, Ceitis zenkeri)

## Table 4.9 Cellulose, Hemi cellulose and Lignin contents continued.

#### Table 4.9b

Compared cellulose etc contents	Mean	Leader	Rank
	difference		
Cellulose vs Hemicellulose	20.4309		
", ", Lignin	9.8376	Cellulose	2
Hemicellulose vs Cellulose	-20.4309		
,, ,, Lignin	-10.5933	Lignin	1
Lignin vs Cellulose	-9.8376	Cellulose	2
,, ,, Hemicellulose	10.5933		

Summary of multiple comparisons for polymeric contents

The anova result showed that the polymeric content is significant (p<0.05) and the summary of the multiple comparisons showed that lignin is the most significant.

#### 4.18 Results of the percentage cellulose content of the wood samples

From the percentage cellulose content of the fifty Nigerian timbers in Table 4.9 and Figure 4.29, it was observed that the cellulose content of the woods ranged between 0.53-133.3% with wood species 17(*barteria fistulosa*) 11(*Anacardium Occidentale* 93.3%) 12(*Irvingia gabonensis* 93.3%), 47 (Annoa Senegalensis 93 3%), having the highest cellulose content, followed by 16 (*Hevea brasiliensis* 83.3%), 25 (*Alstonia congensis* 83.3%) 32 (Tectona grandis 73.3%), 7 (Brachystigia eurecomya 66.6%), 10 (*Naulea diderrichii* 66.6%), 13 (*Albizia ferruguina* 66.6%). 19 (*Pyenarithus angolensis* 66.6%), 46(*Hannoa Klaineana* 66.6%), 49 (*Detarium Macracarpum* 66.6%). 21(*Delonix regia* 63.3%) 43(*Oncoba spinosa* 63.3%), 48 (*Manikara obovata* 63.3%), 9(*Cola gigantia* 60.0%) 35(*Baphia nitida* 60.0% and 37 (*Loncho carpus grif fonianus* 60.0%). 33(*Irvingia gabonensis* 56.7%), 38 (*Ceiba Petandra* 46.7%), 26 (*Ficus elastica* 40.0%), 27(*Anogeissus eiocapus* 40.0%), 31(*Khaya senegalensis* 40.0%) and 36 (*Gmelina arborea* 40.0%). The lowest cellulose content was observed in 3(*Teracarpus soyouxi* 0.53%), while majority of the timber have their cellulose content within 0.53%-36.7%.

Result of this research showed that the values of cellulose of the fifty timbers obtained from the experiment such as 17(*Barteria fistulosa* 133.3%), 11(*Anacardiium occidentale* 93.3%), 12 (*Irvingia* gabonensis 93.3%), 47 (*Annoa senegalensis* 93.3%), 16(*Herea brasiliensis* 83.3%), 25(*Alstonia* cogenesis 83.3%), 32 (*Tectonia grandis* 73.3%), 7 (*Brachystigia eurecomya* 66.6), 10 (*Naulea diderrichii* 66.6%) 13 (*Albizia ferruguinea* 66.6%). 19(*Pyenanthus angolensis* 66.6%), 46 (*Hannoa Klaneana* 66.6%) 49 (*Detarium macrocarpus* 

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66.6%), 21 (*Delonix regia* 63.3%), 43(*Oncoba spinosa* 63.3%), 48 (*Manikara obovata* 63.3%), 9(*Cola gigantia* 60.0%), 35(*Baphia nitida* 60.0%), 37(*Lonchocarpus griffonianus* 60.0%), 33(*Irvingia gabonensis* 56.7%), 38(*Ceiba petandra* 46.7%), 26 (*Ficus platyphilia* 40.0%), 27 (*Anogeissus eiocapus* 40.0%), 31(*Khaya senegalensis* 40.0%), and 36 (*Gmelina arborea* 40.0%), are similar to the literature range of both hardwood and softwood (Kubler, 2010). Thus, the cellulose values for both woods may be similar according to literature of the woods. However some values fell above and below 40.50%. This was attributed to species. Cellulose is a polymer made up of glucose monomers ( $C_6H_{10}O_5$ )n. It has molecular weight of 150,000 to 1,000,000 and contains between 2000 to 3000 glucose units. It is the main component of plant cell walls and plant fibers (cotton: jute etc). The cellulose content of this study ranged from 0.53 – 133.3%. These values were quite encouraging. The high values of cellulose in wood samples are not surprising since it is the main component of plant cell walls. This suggests that they are good sources of raw material for paper industries. 40.0 -133.3% are similar to the literature range of both soft and hard wood (Kubler, 2010).



Figure 4.29: Cellulose content of wood samples

#### 4.19: Results of the percentage hemicellulose content wood samples

Table 4.9 and Figure 4.30 showed that the hemicelluloses content of the fifty Nigerian timbers ranged between 20.0 to 37.0% with 13(Albizia ferruginea) having the highest hemicelluloses content of 37.0% followed by 24(Isoberlina tomemsosa 35.0%), 20(Dialum guincense 35.06) 32(Tectona grandic 33.5%), 7(Biachystigia eurecomya 32.0%) 40 (Mangifera indica 30.00) 50 (Deniella Oliveri 32.0%) 5(Lophura lanceolata 30.2%), 19 (Pyenanthus angolensis 30.0%), 26 (Ficusplatyphilia 30.0%) 34 (Terminatlia superb 30.0%), 36 (Gmelina arborea 30.0%), 38 (Ceiba petandra 30.0%). 39(Bombttxbuonopozense 31.0%), 46(Hannoa Klaineana 30.0%) and 47 (Annoa senegalensis 30.0%). 1(Brachystegia nigeria), 3 (Pteracarphs soyouxi), 16(Herea brasiliensis), 25 (Alstonia congensis), 30 (Triplochiton sclera xylon), 35 (Baphianitida) and 45 (Chlorophora excels) have the lowest hemicelluloses content of 20.0%. 43(Oncoba spinosa 21.8%), 49 (Detarinum macrocarpum 21.08). Majority of the timbers have their hemicelluloses content within 20.0% - 29.0%. Thus the hemicelluloses values of the fifty Nigerian timbers obtained from the experiment, such as 13 (Albizia ferruginea 37.0%), 24(Isoberlina tomensosa 35.0%), 20 (Dialum guinense 35.05), 32 (Tectona grandis 33.5%), 7(Drachystigia eurecomya 32.0%), 40 (Mangifera indica 32.0%), 50 (Daniella oliveri 32.0%), 5(Lophura lanceolata 30.2%) 19(Pyenanthus angolensis 30.0%), 26 (Ficus platyphilia 30.0%), 34(Terminatlia superba 30.0%), 36 (Gmelina arborea 30.0%), 38 (Ceiba petandra 30.0%), 39(Bombax buonopozen 31.0%), 46 (Hamoa kleineana) 47(Annoa seleganensis 30.0%), 43 (Oncoba spinossa 21.8%), 49(Detarium macrocarpus 21.0%) are similar to the literature range of both hardwood and softwood (Kubler 2010). The hemicellulose content depends on wood types. Hardwoods range from 25-35%, while softwood range from 20-30% (Feirer 2000) but from the wood analysis, the hemicelluloses contents ranges from 20.0 - 37.0% which is in accordance to literature. Hemicelluloses are five carbon sugars that are linked in an irregular manner in contrast to the cellulose. Direct covalent linkages exist between the lignin and the hemicelluloses.



Figure 4.30: Hemicellulose content of wood samples
### **4.20:** Results of the percentage lignin content of the wood samples

The results of the percentage lignin content of the wood samples in Table 4.9 and Figure 4.31 showed that the percentage lignin content of the wood sample ranged from 5.6 – 99.4%. 8(Ceitis zenkeri) has the highest percentage lignin content of 99.4% followed by 12(Irvingia gabonensis 90.9%) 35(Pycanantus angolensis 90.9%), 17(Birteria fistulosa 85.4%), 25(Mansonia altissima 85.3%), 4(Garcinia kola 72.2%), 5(Lophura lanceolata 70.5%), 13(Albizia ferruginea 70.5%), 20(Dialum guineanse 66.3%), 26(Linia birins 65.2%), 7(Brachystigia eurecomya 63.2%), 29(Vitex doniaria 42.0%) 37(Lonchocarous griffonianus 48.6%), 38(Ceiba petandra 41.6%) 47(Annoa senegalensis 5.63%) and 19(Pyenantlus angolensis 5.6%) have the lowest percentage lignin content of 5.6%. Others have the following percentage lignin content: 1(Brachystegia nigeria, 33.8%), 28(Naulea popeguinii 36.1%), 34(Terminatlia superba 39.8%) and 50(Daniella oliveri 39.8%). Majority of the timbers have their lignin content within 5.6% - 39.8%. The lignin values of the timbers that fell within 22.0% - 39.8% are similar to the literature range of both hardwood and softwood according to (Regal 2005). From earlier reports, the lignin content for hardwood ranges between 20-25% while the lignin content of softwood ranges between 25-35% (Regal 2005).Lignin is considered the glueing or entrusting substances of wood and add mechanical strength or stiffness to the tree and to the wood. The monomeric unit of lignin are phenolic type compound. Lignin confers hydrophobic properties reflecting the fact that it is based on aromatic rings. Direct covalent linkages exist between the lignin and the hemicelluloses. Soft woods have more extractives and more lignin than hard woods which accounts for the slightly higher heating value. Wood species containing from 5.6 to 25.0% lignin are softwood while those containing from 25% and above are hardwood.



Figure 4.31: Lignin content of wood samples

The elemental composition of the wood samples are shown in Table 4.10 Table 4.10: Elemental Contents of the 50 Tropical Timbers/Wood Studied (ppm)

	Ca	Cu	K	Со	Na	Mg	Cd	Pb	Mn	Fe
1	101.322	0.173	36.522	0.067	9.733	69.942	0.027	0.546	5.162	9.781
2	64.844	0.110	129.258	0.044	5.708	68.717	0.005	0.453	7.357	4.543
3	14.202	0.004	3.577	0.381	73.788	15.266	0.155	1.366	0.225	1.146
4	12.407	0.011	234.345	0.020	33.184	38.274	0.010	0.528	0.669	2.149
5	27.005	0.181	184.592	0.020	18.420	67.933	0.020	0.728	0.682	8.046
6	21.691	0.019	109.047	0.096	83.847	17.080	0.018	2.999	0.780	2.864
7	102.120	0.029	36.050	0.016	56.298	54.030	0.001	1.568	2.156	8.317
8	67.827	0.149	66.959	0.077	5.729	60.042	0.004	0.310	1.704	7.142
9	10.645	0.129	47.738	0.031	14.653	10.088	0.030	0.341	0.324	12.000
10	54.311	0.437	44.827	0.061	11.563	71.384	0,003	0.735	2.445	10.984
11	31.396	1.075	44.260	0.114	11.510	70.972	0.023	0.255	1.051	3.185
12	55.272	0.202	46.337	0.039	38.589	58.907	0.024	0.208	0.729	5.773
13	78.686	0.151	199.399	0.036	5.204	40.130	0.019	0.159	0.860	8.245
14	27.250	0.062	226.499	0.071	16.482	33.100	0.020	0.421	0.549	2.650
15	15.643	0.138	257.296	0.039	14.414	63.840	0.029	0.345	7.938	3.166
16	12.553	0.027	147.264	0.050	18.088	24.944	0.008	0.717	0.287	5.660
17	22.852	0.112	227.668	0.066	20.062	29.416	0.013	0.432	0.422	1.582
18	9.069	0.079	233. 47S	0.045	6.837	20.519	0,014	0.680	0.355	6.155
19	15.415	0.505	51.184	0.043	7.911	59.527	0.003	0.352	0.482	0.549
20	17.970	0.260	126.836	0.006	21.075	72.251	0.044	0.828	0.957	7.369
21	13.963	0.179	233.416	0.118	10.237	31.490	0.004	0.439	0.222	0.656
22	109.550	0.758	183.931	0.069	18.406	68.917	0.035	0.447	4.608	14.315
23	16.345	Nd	76.952	0.125	13.475	21.870	0.010	0,306	0.145	0.358
24	27,829	0.142	56.015	0.051	66.559	30.077	0.304	1.875	0.331	2.237
25	19.000	0.088	106.657	0.565	68.499	41.371	0.006	0.090	0.264	0.932
26	28.639	0.235	35.861	0.032	28.608	67.186	0.015	0.215	8.215	9.263
27	38.504	0.005	134.576	0.088	9.517	46.368	0.011	0.143	0.735	1.389
28	12.894	0.139	91.422	0.027	23.092	15.104	0.025	3.039	0.425	4.225
29	11.815	0.104	19.090	0.025	69.821	17.634	0.329	2.050	0.302	4.375

30	65.7	25	0.02	8	59.832		0.788	52.363	3	69.81	6	0.021		1.28	1	1.45	58	8.85	6
31	18.6	57	0.16	7	109.72	2	0.046	22.696	5	11.26	7	0.000		0.092	2	0.70	)!	35.7	00
32	33.7	59	0.08	3	26.671		0.072	71.910	)	12.42	1	0.232		1.644	4	0.38	31	2.07	4
33	11.2	31	0.008	8	176.57	2	0.478	42.36	l	35.01	7	0.003		0.42	0	0.3	12	1.46	7
34	51.5	63	0708		52.565		0.051	2S.05	8	71.52	7	0.044		0.32	0	2.37	75	3.56	9
35	25.0	12	0.268	8	156.58	4	0.051	15.94′	7	46.19	6	0.010	)	0.32	6	0.89	98	25.1	77
36	30.6	25	0.008	8	103.80	9	0.084	96.36	5	66.19	4	0.008		0.22	2	3.66	50	2.08	0
37	25.1	10	0.118	8	207.41	6	0.071	13.932	2	20.70	9	0.010		0.36	9	0.53	36	13.0	15
38	5.59	4	0.12	1	27.779		0.028	73.63	3	12.10	1	0.314		0.16	7	0.26	59	1.88	9
39	25.1	35	0.291	1	118.24	8	0.631	54.063	3	72.48	2	0.029		0.62	8	2.01	17	13.1	66
40	19.9	93	0.012	2	353.47	3	0.144	20.01	l	19,82	4	0.003		0.05	5	0.27	71	1.60	0
41	18.3	85	0.014	4	102.90	6	0.131	38.534	1	21.51	7	0.004		0.35	5	0.73	31	6.54	3
42	49.0	79	0.119	9	105.39	8	0.056	5.746		28.24	1	0.014		0,33	2	0.98	30	5.91	0
43	18.0	89	0.212	2	54.170		0.071	24.85	5	71.97	5	0.014		0.75	8	2.01	17	16.9	72
44	10.7	65	0.087	7	115.81	9	0.117	9.076		9.864		0.011		0.65	9	0.23	33	2.08	8
45	43.1	94	0,099	Ð	174.81	5	0.066	4.798		46.73	7	0.012		0.30	5	1.25	55	7.69	1
46	26.1	42	0,393	3	11.253		0.028	20.488	3	15.62	9	0.004		0.47	3	0.23	31	1.37	5
47	14.5	51	1.027	7	73.799		0.106	53.13	5	68.01	9	0.014		0.27	3	4.72	27	4.75	9
48	24.4	62	0.066	5	65.864		0,091	8.410		12.73	5	0.000	)	0.37	7	0.31	18	2.90	5
49	14.7	06	0.031	1	121.73	7	0.024	8.130		13.49	5	0.021		0.43	3	0.18	30	1.49	4
50	14.9	44	0.044	4	35.97	9	0.059	20.065	5	15.61	2	0.014		0.32	3	0.51	12	0.46	7
detected		100		100		100		100	10	0	100		100		100		100		100
ange		5.594- 109.550		0.004	-1.075	3.577 257.2	2- 292	0.006- 0.788	4.7 96	798- .366	5.220 72.48	5- 82	0.00	1- )	0.055- 3.037	-	0.145-8	8.215	0.358-35.7
exceeded DA (mg) RC (1989	1	Nil 1200		Nil 1.3-3	.0	56 2000		Nil NS	Ni 50	1 0	Nil 350		Nil NS		Nil NS		Nil 2-5		Nil 10-15
o contribut	ted	0.4-9.13		0.16-	43	0.18-	13	NS	10	-19	1.5-2	2.1	NS		NS		NS		2.7-275
RDA																			

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WHO 2001	3,600-8000	73	10-100	100	400-500	100-200	60	214	NS	48000
ppm	(Ceiba petandra, newbodia loevis)	(Pteracarpus soyouxi, Anacardium occidentale)	(Pteracarpus soyouxi, Canarium schwafurihii)	(Dialum guinense, Triplochi ton scleroxyl on)	(Chlorop hora excels, Gmelina arborea)	(Pteracarp us soyouxi, Bombax buonopoze nse)	(Brachyst egia eurecomy a, Vitex doniana)	(Mangife ra indica, Naulea popeguini i)	(Manikara obovata, Ficus elastica)	(Mansonia altisima, Khaya senegalensis)

# Table 4.10b

Summary of multiple comparisons for elemental contents

Compared elemental contents	Mean difference	Leader	Rank
Ca versus Cu	31.5667		
,, ,, K	-77.1545		
", ", Co	31.6429		
,, ,, Cd	31.7150		
,, ,, Pb	31.1071		
,, ,, Mn	30.2559		
,, ,, Fe	25.5977	Ca	8
Cu versus Ca	-31.5667		
,, ,, K	-108.7212		
,, ,, Na	-29.1296	Na	5
,, ,, Mg	-40.3670		
K versus Ca	77.1545	Κ	1
,, ,, Cu	108.7212		
" " Co	108.7974		
,, ,, Na	79.5916		
,, ,, Mg	68.3542		
,, ,, Cd	108.8695		
,, ,, Pb	108.2616		
,, ,, Mn	107.4105		
,, ,, Fe	102.7523		
Co versus Ca	-31.6429		
,, ,, K	-108.7974		
,, ,, Na	-29.2058	Na	4
,, ,, Mg	-40.4432		
Na versus Cu	29.1296		
,, ,, k	-79.5916		
" " Co	29.2058		
,, ,, Mg	-11.2374	Mg	10
,, ,, Cd	29.2779	_	
,, ,, Pb	28.6700		
,, ,, Mn	27.8189		
,, ,, Fe	23.1607		

Mg versus Cu	40.3670		
", " k	-68.3542		
", ", Co	40.4432		
,, ,, Na	11.2374		
,, ,, Cd	40.5153		
,, ,, Pb	39.9074		
,, ,, Mn	39.0563		
", ", Fe	34.3981	Mg	2
Cd versus Ca	-31.7150		
,, ,, K	-108.8695		
,, ,, Na	-29.2779	Na	3
,, ,, Mg	-40.5153		
Ph versus Ca	-31.1071		
,, ,, K	-108.2616		
,, ,, Na	-28.6700	Na	6
,, ,, Mg	-39.9074		
Mn versus Ca	-30.2559		
,, ,, K	-107.4105		
,, ,, Na	-27.8189	Na	7
,, ,, Mg	-39.0563		
Fe versus Ca	-25.5977		
,, ,, K	-102.7523		
,, ,, Na	-23.1607	Na	9
,, ,, Mg	-34.3981		

The anova result also showed that the element content is significant (p<0.05) and the summary of the multiple comparisons (Table 4.10b) showed that potassium is the most significant followed by magnesium and lastly sodium.

#### **4.21:** Results of calcium content of the timber

The result of the calcium content in Table 4.10 and Figure 4.32 showed that calcium content of the wood ranged between 5.594 ppm - 109.550 ppm 22 (Newboudia laevis) has the highest calcium content of 109.550 ppm, followed by the following: 1 (Brachystigia nigeria 101.322) ppm), 7 (Brachystigia eurecomya 102.120 ppm), 13 (Albizia ferruginea 78.686 ppm), 2(Hamoa klaineana 64.849 ppm), 8 (Ceitis zenkeri 67.82 ppm), 30 (Triploclinton scleroxylon 65.725 ppm), 12(Irvingia gabanonesis 55.272 ppm), 10 (Nauclea diderrichii 54.311 ppm) and 34 (Terminatlia superba 51.563 ppm). Low calcium content was observed in 42(Khaya ivorensis 49.079ppm) and 45(Chlrophora excels 43.194 ppm), 27 (Anogeissus eiocapus 38.504 ppm), 11 (Anacardium occidentale 31.396 ppm), 32 (Tectora grandis 33.759 ppm) and 36 (Gmelina arborea 30.625 ppm). The calcium content of most wood species fell within 5.594 ppm- 28.639 ppm, 38 (Ceiba *petandra*) has the lowest calcium content of 5.594 ppm. From the above results, it can be deduced that woods with high calcium content will release more energy than those with low calcium content when consumed and as such will aid in producing strong bone and also in preventing deformity. Minerals are necessary for body metabolism. They help in adding mechanical strength to bones: They are components of enzymes and hormones and functions as buffers and regulate the balance and improvement of fluid in and out of cells. Cooking reduces the amount of some metals. The RDA values of Ca for adult men with 3000k/day, recommended energy intake is 1,200mg. This value implies that for Ca which is needed for growth and maintenance of bone, teeth and muscles the timber cannot contribute meaningful amount dietary Ca. The values from 12 and above is high compared with the Ca content of indigofera astragoline leaves the Ca content of Indigofera astragolina leaves (Gafer et al., 2011). Despite the low value, but compare to others (K, Na, Mg, Co, Mn, Fe, Pb, Cd and Cu contents), the studied wood samples are good sources of calcium.



Figure 4.32: Calcium content of wood samples

### 4.22: Result of the copper content of the fifty nigerian timbers

Table 4.10 and Figure 4.33 showed that copper content of the wood species ranged between 0.004 - 1.075 ppm. Wood number 11(Anacardium occidentale) has the highest copper content of 1.075 ppm followed by 34 (Terminatlia superba 0.708ppm), 19 (Pyenanthus angolensis 0.505 ppm), 10 (Naulea diderrichii 0.437 ppm), 46 (Garcinia gnetrides 0.393 ppm), 20 (Dialum guinense 0.260 ppm), 26 (Ficus elastica 0.235 ppm), 35 (Baphia nitida 0.268 ppm), 39 (Bombax buonopozense 0.291 ppm) and 43 (Oncoba spinosa 0.212 ppm). The average copper content in the various woods were observed in 1 (Brachystegia nigeria 0.173 ppm), 2 (Harmoa klaineana 0.110 ppm), 5(Lophura lanceolata 0.181 ppm), 8 (Ceitis zenkeri 0.149ppm), 9(Cola gigantia 0.129ppm), 13 (Albizia ferrunginea 0.151 ppm), 15 (Canarium schwafurihii 0.138ppm), 17(Barteria fistulosa 0.112 ppm), 21 (Delonix regia 0.179 ppm), 24 (Isobelina tomensosa 0.142 ppm), 28 (Naulea popeguinii 0.139 ppm), 29 (Vitex doniana 0.104 ppm), 31 (Khaya senegalensis 0.167 ppm), 37 (Lonchocarpus griffonianus 0.118 ppm), 38 (Ceiba petandra 0.121 ppm) and 42 (Khaya ivorensis 0.119 ppm), while low copper content were observed between 0.004 ppm - 0.99 ppm. The lowest copper content was observed in 3(Pteracarpus soyouxi) with copper value of 0.004ppm. The copper content recorded in this study was remarkably lower than the published for garlic (Cu 30-300 mg) Kabata-pendias and Pendias, (1984). These results are also lower than the WHO maximum limit of metals in vegetables. The WHO maximum limit of some metals in vegetables are Pb, 0.3mg/kg, Zn 100 mg/kg, Cd 0.1mh/kg, Mn 500mg/kg, Fe 425mg/kg, Cu 73mg/kg, Na 67mg/kg, Co 50mg/kg and Cr 100mg/kg. (FAO/WHO, 2001). Result of this research showed that all the values of fifty Nigerian timbers were lower than the experimental values of vegetables by Alloway, 1995. The levels of Cu in the fifty tropical timbers were lower than 30µg-g reported for teek leaves (Mozafar et al., 2000). The copper content of wood sample number 23(Mansonia altissima) was below detection limit. Copper plays a role in haemogloin formation and it contributed to Iron and energy metabolism. The RDA values for Cu is 1.5 - 3mg for a male adult and 0.16% - 42% are contributed to the RDA by the wood samples. This means that some of the wood samples are rich sources of copper while some are poor sources of copper.



Figure 4.33: Copper content of wood samples

#### **4.23:** Result of potassium content

From Table 4.10 and Figure 4.34, it showed that the potassium content of the wood samples ranged between 3.577 ppm – 257.296 ppm. The wood sample number 15 (Canarium schwafurihii) has the highest potassium content of 257.296 ppm followed by 4 (Persea Americana 234.345 ppm), 14 (Azadirachta indica 226.449 ppm), 17 (Barteria fistulosa 227.668), 18 (Teraplura terapera 233.449 ppm), 21 (Delonix regia 233.416), 37 (Lonchocarpus griffonianus 207.416 ppm) moving in descending order, the decrease in percentage of potassium content follows the following trend:15>4>18>21>17>14>37>13>5>22>33>45>35>40>16>27>2>20>49> 44>6>25>31>36>41>42. Wood number 3(*Pteracarpus soyouxi* 333.577ppm) has the lowest value of potassium. Wood ash typically include 10 - 30% potassium oxide. Potassium is part of NKP fertilizer which are the most essential elements for plant growth. Potassium works with sodium to equalize the acid alkaline balance in the blood. In correct ratio, sodium and potassium regulate water balance in the body. The recommended daily allowance RDA of potassium is 200 mg for adults (NRC, 1989). K/Na ratio in the diet assist in the prevention of hypertension and arteries scherosis and for normal protein retention during growth stages the level should be within the range of 3 - 4. The wood sample are 0.18% - 13% to the RDA. They are poor sources of potassium.



Figure 4.34: Potassium content of wood samples

### 4.24 Result of cobalt content

The results of experiment in Table 4.10 and figure 4.35 showed that samples ranged between 0.006 ppm – 0.788 ppm. Wood number 30(*Tripochiton sceleroxylon*) has the highest cobalt content of 0.788 ppm while wood number 20 (*Dialum guinense*) has the lowest cobalt content of 0.006 ppm. The decreasing trend of the cobalt content of the timbers are 39(*Bombax buonopozensis* 0.63 ppm), 25 (*Alstonia cogenesis* 0.565 ppm), 33(*Irvingia grandifolio* 0.478ppm), 3(*Pteracarpus soyouxi* 0.381ppm), 11(*Anarcadium occidentale* 0.11 ppm), 21(*Delonix regia* 0.11ppm), 23(*Mansonia altissima* 0.125ppm), 40(*Mangifera indica* 0.144 ppm), 41(*Xylopia aethiopica* 0.11 ppm), 44(*Anihodesta dejenalensis* 0.117 ppm), 47(*Annoa senegalensis* 0.106 ppm). The average percentage of cobalt content in the various wood were observed in the range between 0.006 ppm – 0.096 ppm. The values of the cobalt content of the wood samples studied in this research were lower than published values considered toxic for mature plant tissue. Cobalt is a component of vitamin B<sub>12</sub>. Deficiency of cobalt in the body leads to loss of appetite, emaciation and restlessness. All these essential minerals serve as the base material in the production of drugs.



Figure 4.35: Colbalt content of wood samples

### 4.25 Result of sodium content of fifty Nigerian timbers

From the sodium content of some fifty Nigerian timbers in Table 4.10 and Figure 4.36, it was observed that the sodium content ranged from 4.798 ppm – 96.366 ppm. Wood sample number 36(Gmelina arborea) has the highest sodium content of 96.366 ppm followed by 6(Albizia zygia 83.847 ppm), 38(Ceiba petandra 73.633 ppm), 32(Tectona grandis 71.910ppm), 3(Pteracarpus soyouxi 73.788 ppm), 24(Isoberlina tomensosa 66.559ppm), 25(Alstonia congensis 68.499ppm), 29(Vitex doniana 69.821 ppm), 39(Bombax buonopozense 54.063 ppm), 47(Annoa senegalensis 53.135 ppm), 33(Irvingia grandifolio 42.361 ppm), 41(Xylopia aethiopica 38.534 ppm), 4(Persea America 33.184 ppm) and 12(Irvingia gabonensis 38.589 ppm). The average sodium content in the various wood was observed in the wood samples 26, 34, 28, 43, 31, 20, 17, 40, 46, 50, 5, 11, 22, 14, 35, 9, 15, 23, 37, 10, 11 and 21 (i.e. between the range 11.510 ppm – 28.608 ppm). The lowest sodium content was observed in the wood samples 45(Chlorophora excelsa 4.798ppm) followed by 42(Khaya ivorensis 5.746 ppm) 13(Albizia ferruginea 5.204 ppm), 8(Ceitis zenkeri 5.729 ppm), 2(Hamoa klaineana 5.708 ppm), 18(Teraplura terapera 6.837 ppm), 19(Pyenanthus angolensis 7.911ppm), 48(Manikara obovata 8.410ppm), 49(Naulea latifolia 8.130ppm), 44(Anihodesta dejanalensis 9.076ppm), 1(Brachytegia nigeria 9.733 ppm) and 27(A nogeissus eiocapus 9.517ppm). The results of this research showed that the value of all the wood samples obtained from the experiment were low compared to the experimental values of the leaf by Adesuyi et al., 2011 whose value was 105.366ppm and by Compaore et al., (2011) whose value was 98.798ppm. Sodium works with potassium to equalize the acid alkaline balance of the blood. In the correct ratio, sodium and potassium regulate water balance in the body. The RDA value for sodium for adult is 500mg (NRC, 1989). Because of the high sodium content in the wood samples, it could be a good source of food for hypertensive patients. The wood samples contribute 10% - 19% to RDA and therefore are poor sources of the element.



Figure 4.36: Sodium content of wood samples

### 4.26 Result of magnesium content

The result of the magnesium content of the wood samples showed that the magnesium content (fig. 4.37) ranged between 5.266 ppm - 72.482 ppm. The wood sample number 39(Bombax buonopozense) has the highest magnesium content followed by 10(Naulea diderrichii 71.384 ppm), 11(Anacardium occidentale 70.922 ppm), 20(Dialum guineense 72.25 ppm), 34(Erminatlia superba 71.527ppm), 43(Oncoba spinosa 71.975 ppm), 1(Brachystegia nigeria 69.942ppm) 2(Hamoa klaineana 68.942 ppm), 5(Lophura lanceolata 67.933 ppm), 22(Newbodia laevis 68.917ppm), (Ficus elastica 67.186 ppm), 30(Triplochiton sceroxylon 69.814ppm), 36(Gmelina 47(Annoa senegalensis 65.019ppm), 8(Ceitis zenkeri 60.042ppm), arborea 66.194 ppm), 15(Canarium schwafurihii 63.890ppm), 19(Pyenanthus angolensis 59.50ppm), 12(Irvingia gabanonensis 58.907 ppm), 7(Brachystegia eurecomya 54.030ppm), 27(Anogeissus eiocapus 46.368ppm), 35(Baphia nitida 46.196 ppm), 45(Chlorophora excelsa 46.737 ppm), 25(Alstonia congensis 41.371ppm), and 13(Albizia ferruginea 40.730ppm). The lowest magnesium content was observed in 3(Pteracarpus soyouxi 5.266ppm). Other samples with lower values in increasing order follows the following trend 44 < 9 < 31 < 32 < 38 < 48 < 49 < 28 < 29 < 6 < 40 i.e. 44 (anilodesta dejenalensis 9.864ppm),<9(Cola gigantia 10.088ppm),<31(Khaya senegalensis 11.267ppm),<32( Tectona grandis 12.421ppm),<38(*Ceiba petendra* 12.101ppm),<48(*Manikara obovata* 12.735ppm), 49(Naulea latifolia 13.495 ppm), 28(Naulea popeguinii 15.104 ppm), 29(Vitex doniana 7.634ppm), 6(Albizia zygia 17.080 ppm), 40(mangifera indica 19.824 ppm). The result of this research indicated that the magnesium values for the wood species obtained from the experiment were very low when compared with the experimental values of seed. The magnesium values of this research 5.266ppm – 72.482 ppm were lower than values reported by Mozafa et al., (2000). Magnesium is necessary for many enzymes. It helps in carbohydrates metabolism and is necessary for the function of nervous system. The values are high compared with 2.56mg/100g in Diospyros mespiliformic (Hassan et al., 2005) and 23.18 of Amaranthus hybridus leaves (national research council 1989). The RDA value for Mg for adults male is 350mg and the fifty timbers contribute 1.5% - 21%. This implies that the wood samples are poor source of Mg. Magnesium is an important mineral element in connection with circulatory diseases such as heart disease and Ca metabolism in bone (Iwasa et al., 1998, Hasan et al 2005).



Figure 4.37: Magnesium content of wood samples

### 4.27 Results of cadmium content

The result of cadmium content of the wood samples in Table 4.10 and Figure 4.38 showed that the cadmium content of the wood ranged between 0.001 ppm - 0.329 ppm. The wood sample number 29(Vitex donina) has the highest cadmium content followed by 24(Isoberlina tomensosa 0.304ppm), 38(Ceiba petandra 0.314 ppm), 32(Tectona grandis 0.232 ppm), 3(Pteracarpus soyounxi 0.155 ppm), 20(Dialum guineense 0.44 ppm), 9(Cola gigantia 0.030 ppm), 22(Newbodia laevis 0.035 ppm), 1(Brachystegia nigeria 0.027 ppm), 5(Lophura lanceolata 0.020 ppm), 11(Anarcadium occidentale 0.023ppm), 12(Irvingia gabanonensis 0.024ppm), 14(Azadirachta indica 0.020 ppm), 15(Canarium schwafurihii 0.029 ppm), and 28(Naulea popeguinii 0.025 ppm). The average cadmium content yield in various woods were observed between the range 0.001ppm - 0.019ppm while the lowest cadmium content was observed in 7(Brachystegia eurecomya 0.001ppm). The result of this research indicated that the values for the wood samples obtained from the experiment were low when compared to the experimental values of leaves of the plants by Uwah (2009) whose value was 0.5mgg<sup>-1</sup>. WHO (1999) maximum limits of metals in are:Pb=0.3ppm,Zn=100ppm,Cd=0.1ppm,Mn=500ppm,Fe=425ppm - Cu=73ppm, plants Ni=67ppm, Co=50ppm



Figure 4.38: Cadmium content of wood samples

### 4.28 Result of lead content

Table 4.10 and Figure 4.39 showed the result of lead content of the fifty Nigerian timbers. The lead content of the wood ranged between 0.055 ppm – 3.037 ppm. Wood number 28(Naulea popeguinii) has the highest lead content of 3.037 ppm followed by 6 (*Albizia zygia* 2.99ppm), 29(*Vitex doniana* 2.050 ppm), 3(*Pteracarpus soyouxi* 1.366 ppm), 7 (*Brachystigia eurecomya* 1.56 ppm), 24(*Isoberlina tomensosa* 1.875 ppm), 30(*Triplochiton scleroxylon* 1.281 ppm) and 32(*Tectona grandis* 1.414 ppm). Most wood have their lead content between 0.055 ppm – 0.875 ppm. The wood number 40 (*Mangifera indica*) has the lowest lead content of 0.055 ppm. Thus the lead content of the fifty Nigerian timbers studied were not similar to the experimental values of plant leaves by Updegroff (1969). The values from 0.4ppm – 0.6pp were similar to those recorded by Updegroff., 1969 for plant leaves. Values above 0.6ppm were higher 0.6ppm was higher and values below 0.4 were lower than that recorded by Updegroff 1969. Presence of lead in the wood is attributed to forests located at heavy traffic area (inevitable spilling of gasoline and engine oils and discarded lead acid batteries).



Figure 4.39: Lead Content of wood samples

### 4.29 RESULT OF MANGANESE CONTENT

The result of experiment in Table 4.10 and Figure 4.40 showed that the manganese content in the timber samples ranged between 0.145ppm – 8.215ppm. Wood number 26(Ficus elastica) has the highest manganese content of 8.215 ppm, followed by 15(Canarium schwafurihii 7.938 ppm), 2(Hamoa klaineana 7.357 ppm) 29 (Vitex doniana), 1(Brachystegia nigeria 5.162 ppm), 22(Newbodia laevis 4.608 ppm), 47 (Annoa senegalensis 4.727ppm), 36(Gmelina arborea 3.660 ppm), 34 (Terminatlia superba 2.876 ppm), 10(Naulea diderrichii 2.445ppm), 7(Brachystegia eurecomya 2.156 ppm), 39 (Bombax buonopozense 2.047 ppm), 43(Oncoba spinosa 2.017 ppm), 8(Ceitis zenkeri 1.704 ppm), 30(Triplochiton scleroxylon 1.459 ppm), 45(Anarcadium occidentale 1.051 ppm). The average manganese content in the various wood ranged between 0.145ppm -0.898 ppm. That is, 42(Khaya ivorensis 0.950 ppm), 20(Dialum guinense 0.957 ppm), 35(Baphia nitida 0.898 ppm), 13(Albizia ferruginea 0.860 ppm), 6(Albizia zygia 0.780 ppm), 12(Irvingia gabononensis 0.729 ppm), 27(Anogeissus eiocapus 0.735 ppm), 31(Khaya senegalensis 0.701 ppm), 41(Xylopia aethiopica 0.731 ppm) etc. The lowest manganese content was observed in 23(Manikara obovata 0.145 ppm). The result of this research showed that the values of all the wood species obtained from the experiment were low compared to the experimental values of plant seeds by Mozafar et al. (2000) whose manganese values was 10.35ppm. Manganese is another microelement essential for human nutrition. It acts as in activator of many enzymes (McDonald et al., 1995). The range values is lower than 0.98 - 38.0 mg/100g reported in some locally green leafy vegetables and 11.6mg/100g in Balassam apple (Momordica balsamina L) leaves (Hassan and Umar, 2006). The RDA value for manganese is 2 - 5 mg/100 g for a male adult (NRC, 1989). The fifty Nigerian timber can contribute 4 % - 205 % of the RDA some of them are rich sources of Manganese.



Figure 4.40: Manganese Content of wood samples

### 4.20 Result of iron content

The result of experiment in Table 4.10 and Figure 4.41 showed that the iron content in the timber samples ranged between 0.358 ppm – 35.700 ppm. Wood number 31(Khaya senegalensis) has the highest iron content of 35.700 ppm followed by 35(Baphia nitida 25.177ppm), 39(Bombax buonopozense 13.166 ppm), 43(Oncoba spinosa 16.972 ppm), 9(Cola gigantia 12.000ppm), 10(Naulea diderrichii 10.984 ppm), 1(Brachystegia nigeria 9.781 ppm), and 26(Ficus elastica). The lowest iron content was observed in 23(Mansonia altissima 0.145 ppm). The result of this research showed that the value of all the wood species obtained from the experiment were low compared to the experimental values of plant seeds by Adesuyi et al. (2011) whose value was 50.056 ppm. Iron is a constituent of heamoglobin which transports oxygen for metabolism and energy production. Presence of iron could be attributed to geochemistry ruling out anthropogenic sources. These elements at low concentrations would help in the synthesis of keratine for hair/wool growth, muscle contraction, nerve stimulation, geochemistry ruling out anthropogenic sources. haemoglobin formation and enhancement of the immune system. The result of this research showed that the value of all the wood species were low compared to the experimental values of plant seeds by Adesuyi et al. (2011) whose value was 50.055ppm. From 3.00ppm and above are higher than 2.80 mg/100g in T. terrestris and in some cultivated vegetables such as spinach (1.6Mg/100g), lettuce 0.7mg/100g and cabbage 0.3 mg/100g (Turan *et al.*, 2003) but lower than 70.00 mg/100 g in Cassia siamae (Ngaski, 2006) and 84.4mg/100g in Helmintho stachyssp. The RDA value for a male adult is 10-1 mmg (NRC, 1989). The wood samples can contribute 2.7 %-275 %. The wood samples are rich sources of Iron and could be of good use to pregnant women, lactating mothers. Generally for women since they loss some quantity of blood during monthly menstruation. It could help in the nourishing of their bodies. Iron is required for haemoglobin formation and its deficiency leads to anaemia (Turan, 2003).



Figure 4.41: Iron content of wood samples

### **CHAPTER FIVE**

### Summary, Conclusion and Recommendation

### 1.1 Summary

A thorough literature check shows that there is no published work on the chemistry of tropical timbers, but a voluminous one on the temperate timbers .The chemistry of fifty tropical timbers were evaluated.The ANOVA results obtained showed that the phytochemical contents , the proximate contents ,the polymeric contents and the elemental contents of the fifty timbers were significant. Multiple comparison showed that protein content is the most significant among the phytochemicals followed by flavonoid and cardiac glycoside;Crude fibre content is the most significant among the proximate analysis followed by fibre saturation point and lastly fibre length, lignin content is the most significant among the elemental contents followed by magnesium.

# 5.2 Conclusion

The study determined the physico-chemical and elemental composition of fifty tropical timbers. The result obtained indicated that some of the timber are rich sources of polymeric and phytochemital. These values are low when compared to experimental values of non-woody parts of plants.

From the results and discussions, the values for cellulose contents were 0.53-133.3% and are quite encouraging. This suggested that the fifty tropical timbers were good sources of raw material for paper industries since cellulose is the basic constituent of paper. In this research, the hemicelluloses values ranges from 21.0% to 37.0% and are similar to those recorded in literature. Lignin is considered the glueing or entrusting substances of wood and add mechanical strength or stiffness to the tree and to the wood . Wood species containing from 5.6 to 25.0% lignin are hard wood while those containing from 25% above are soft wood. Some examples of hard wood are *Hamoa klaincana*,*Pteracarpus soyouxi*, *Albuzia zygia* and *cola gigantia* while some examples of soft wood are *Brachystegia nigeria*, *Garcinia kola*, *Lophura lanceolata and Brachystigia eurecomya*. The phytochemical analysis of the fifty Nigeria timbers showed the presence of saponins, flavonoids, alkaloids, tannins, resins, protein, carbohydrate and cardiac glycoside. All these phytochemical compounds present are used for pharmarceutical. These compounds serve as the basic material in the production of antibiotics. Since many infection agents are becoming resistant to synthetic drugs therefore these timber extracts have the major advantage of being the most effective and cheaper

alternative sources of drugs. Moisture content ranged from 9.20-34.40%. Some of the tropical woods had moisture content higher than those of some common Nigeria leafy vegetables such as *xanthosem sagittfolum* (14.7%), *Gnetum buchholsionium* (33.8%), *Vernonia amygdaline* (27.4%) and *Adansonia digitata* (9.5%). This indicated that some of the tropical timbers are found rich in mineral elements while some are low in mineral content. Woods that contained below 2.50% ash content had low ash while woods that contained above 2.50% had high ash content. Some examples of woods with high ash contents are: *Azadirachta indica, Hevea brasiliensis* and *Dialum guineense*. While wood with high ash contents are *Brachystegia Nigeria, Hamoa klaineana, Pteracarpus soyouxi* and *Garcinia kola*. The thermal conductivity of the timbers ranged from 182.00-105665.00 mmh. Wood charring is the primary factor that determines the load-carrying capacity of woods with high rate of charring temperature would have ability of load carrying capacity.

The pH recorded in this study for the timbers agree with literature report that wood is generally acidic. pH ranged from 4.10-6.72. The fiber saturation point has significance in that it is a point at which there is an abrupt change in certain physical properties that vary with the moisture content. Shrinkage occurs when wood loses moisture below the fibre saturation point. Above that point, wood is dimensionaly stable. The fibre saturation points of the woods ranged from 21.0-28.5%. The solubility values of the timbers for four different solvents are lower than that recorded for non-woody plants like pandaus candelabrium root (30.50%) and leaves (26.75%). The solubility values showed that solubility in 1% NaOH was higher than the solubility in the other three solvents -cold water, hot water and ether. The fifty tropical wood samples contained some essential minerals which are of great importance in the formulation of animal feeds. The low acid values and free fatty acid values indicated that the wood samples are good for human consumption. The saponification values of the wood oils suggested that the were good for making liquid soap and shampoo. The low peroxide values obtained for oils these oils showed that they were not susceptible to oxidation. The range of values of the lodine values indicated that they were non-drying oils and could be used in making alkyd resin, binders in paints, varnish and plasticizers. This analysis had shown that tropical timbers could be good sources of food nutrients or food supplements. Since many infection agents are becoming resistant to synthetic drugs, therefore wood extracts have the major advantage of being the most effective and cheaper alternative sources of drugs manufacture.

### 5.2 **RECOMMENDATIONS**

This work has found tree species with increased chemical and physical compositions and is recommending them for use in pharmaceuticals, building and construction as well as afforestation. The plant species can be hernessed and new drugs manufactured from them. Also there is need for dosage, toxicological effects and structure of active compounds to be investigated. Much work still has to be done on the plants to determine exhaustively the chemical constituents present using more analytical instruments like Nuclear Magnetic Resonance (NMR): Mass Spectrometer, GC-MS and Ultraviolet Spectrometer. The physiochemical properties of the fifty Nigerian timbers considered in this work suggested that they should be used as good ingredients in cosmetics, animal feed, beverage, pharmaceutical industries and paper industries.the result of the polymeric content shoed that they could be used for production of plastics, lignochemicals, as good as ingredients in textile industry and textile production.

# 5.3 Contribution to knowledge

- i. This work has supplied valuable information about the physico-chemical and metal content of selected tropical timbers in Nigeria.
- ii. This research has shown a better source of the various timber species which will save time and effort in trying to ascertain a sourcing material when the need arises.
- iii. This research has confirmed the chemistry of tropical timbers instead of temperate timbers.
- iv. Current levels of the physico-chemical polymeric and metal content of the selected tropical timbers have been determined
- v. The results of this study will form reference (data base) for Nigeria timbers.
- vi. Ample information from this work is available for the regulatory bodies in the country to work with.
- vii. The result of this study will for a future reference (Data base) for Nigeria timbers.

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