UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

ASSESSING THE USE OF BONDED SAWDUST AS A SUBSTITUTE MATERIAL FOR CARVING IN GHANA, CASE STUDY AT KUMASI METROPOLIS IN ASHANTI REGION

GORDON OWUSU YEBOAH

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A Dissertation in the DEPARTMENT OF WOOD AND CONSTRUCTION TECHNOLOGY EDUCATION, Faculty of TECHNICAL EDUCATION, submitted to the School of Graduate Studies, University of Education, Winneba, in partial fulfillment of the Requirement for the award of the Master of Technology Education (Wood) degree

JUNE, 2022

DECLARATION

STUDENT'S DECLARATION

I, **GORDON OWUSU YEBOAH**, declare that, this Dissertation with the exception of quotations and references contained in published works which have all been identified and acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE:……

DATE:……

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of the Dissertation were supervised in accordance with the guidelines on supervision of Dissertation laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: **MR. JOSEPH ASOMANI**

SIGNATURE:…….

DATE:…….

DEDICATION

This research report is dedicated to Almighty God, My Refuge, for bringing me to this far. Also to my lovely wife Georgina Pomaa (Sofomaame) and my lovely kids Anita (Ani), Chris (Pastor), Marvin (Apostle) and Monic (Nkunim) Owusu Yeboah for their encouragement and support not forgetting my dear mother Monica Agyemang Yeboah.

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ABSTRACT

The purpose of this study was to assess the use of sawdust as a substitute for carving material. The research adopted cross-sectional survey design for the study. The research adopted deductive and inductive research approaches. The population for the study was 340. Stratified random sampling technique was used to obtain the sample size of 184. Questionnaire was the main instrument used to gather primary data. Statistical Package for Social Scientists (SPSS version 20.0) was used to analyze data. The data was analyzed using descriptive and inferential statistics. The study results indicated that although bonded sawdust could be carved just as wood, experiment revealed that only extremely well sharpened tools could do the carving to expectation. Any blunt tool was found to peel the mould off rather than carved it. It was revealed in the research that pieces carved out of bonded sawdust would be best for interior use than exterior usage. This was because bonded sawdust could not withstand rain as compared to wood. Bonded sawdust that came into contact with rain were susceptible to reverse to their original state if handled well and left to dry. The study results show that the factors that influence timber species selection for carving works were durability, mechanical and physical properties (ranked 1st), Quality (ranked 2nd), Appearance (ranked 3rd), Processability (ranked 4th), Type of product (ranked 5th), Availability (ranked 6th), Price (ranked 7th), Affordability (ranked 8th), Thickness sizes (ranked 9th), Sustainability (ranked 10th), Suitability (ranked 11th), Informed decision (ranked 12th), Area of usage (ranked 13th), and Expert advice (ranked 14th). The study concluded that sawdust could be used as carving material and fashion into blocks and boards to serve as a substitute material for carving and the quality of carved pieces from sawdust boards could be compared to solid boards. The study recommended that planned orientation programme should be organized for wood carvers to acquaint them with the use of bonded sawdust as a substitute material for carving.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The increase in population and human activities in Ghana has rapidly pulled up a high demand of buildings to house individuals and activities (i.e. the provision of residential, commercial, industrial or the combination of any of the building categories). However, the demand for building has beckoned the activeness of the Building Construction Industry (BCI) to support in whinging the wheels of development, especially in developing countries (Ofori, 2010).

The BCI is characterized by three main resources; human, plant and equipment, and material resources. Notwithstanding the importance of the mentioned resources, the impact of the material resource in building construction (BC) should not be undermined (Fergusson, 2010). Bentum, (2017), asserts that building materials account for nearly 60% to 65% of the total cost of building construction. The demand for materials either locally obtained or imported has pulled an array of different industries to play roles in the construction industry and the list of these industries is not complete without mentioning the timber industry.

Oteng - Amoako (2018), did some work on the natural resistance of the wood of *Terminalia ivorensis to* fungi and termites. Oteng - Amoako (2018). Ocloo and Usher (2019) also did extensive work on the resistance of 85 Ghanaian hardwood timbers to damage by subterranean termites. In that work 8 of the species under study in this thesis were included. Ocloo (2015) worked on stress grading West African timbers suitable for construction work. Kollman, and Cote, (2014), did some work on 14 less-utilised species; including *Amphimas pterocarpoides* (Yaya), *Antiaris toxicaria* (Kyenkyen) and *Canarium schweinfurthii* (Bediwonua).

The work was done under laboratory conditions. He found out that *Amphimas pterocarpoides* (Yaya) was not durable for construction work when subjected to fungal attack. Oteng-Amoako et al (2018) worked on the identification of 14 lesser utilized species. Gyimah-Boadi (2019) also worked on the treatability and durability of some of the less utilized species including *Antiaris toxicaria* (kyenkyen) and *Petersianthus macrocarpus* (Esia).

He found out that though *Antiaris toxicaria* is not durable it is permeable so can be impregnated to enhance its durability for construction work. *Petersianthus macrocarpus* was found to be resistant to treatment. Marfo, (2010), also exposed *Amphimas pterocarpoides* (Yaya) to termite attack and found that, its durability was highly increased when treated with creosote and moderately high when untreated. Huang *et al*. (2014), who worked on some less-utilized Ghanaian hardwoods, reported that *Sterculia rhinopetala* (Wawabima) was very durable after 12 weeks exposure to white rot and brown rot fungi.

Okoh (2017) worked on water absorption of some Ghanaian species, of which, *Petersianthus macrocarpus,* was include in his work. By comparing the European species with the Ghanaian species, he concluded that at higher temperatures, the European species were more hygroscopic. Oteng-Amoako *et al*. (2018) recently provided a macroscopic identification manual for 100 tropical African species including mostly less utilized species.

Most of the earlier works on the Ghanaian woods were on the primary well known species including a few of the lesser utilized species. The anatomical work carried out by Oteng-Amoako et al. (2018) was to aid in the identification of the wood macroscopically while this study sought to use both the microscope and scanning electron microscope to help understand the woods of the nine LUS better. Wimmer

(2011) reported that absorption/strength properties were mainly influenced by cell-wall thickness.

This study set out to find out whether some anatomical properties had influence on properties such as durability and strength that is suitable for construction works. The weight and strength properties of wood, together with the behaviour of wood in

+Simpson and TenWolde (2019) reported that the versatility of wood was demonstrated by a wide variety of products. This versatility was a result of a wide spectrum of desirable physical characteristics or properties that the many species of wood possess. In many cases, more than one property of wood was important for an end product. For example, to select a wood species for construction works, the value of appearance, such as texture, grain pattern, or colour, may be evaluated against the influence of characteristics such as machinability, dimensional stability, or decay resistance.

In spite of the countless number of environmental campaigns, both locally and internationally, the rich forest lands continue to deplete at a threatening speed (Okra 2002). The timber industry is widely opening up and as a result, it is adversely adding to deforestation. Dei (1990) revealed that even though there is no data on the quantity of wood felled for carving, wood carving activities contribute immensely to the alarming growth rate of deforestation in Ghana. Okra (2012) shared that the government of Ghana's 15-Year Tourism Master Plan (1996-2010) called for the development and promotion of the trades' internal and external markets. This has obviously resulted in a quick jump in the use of wood for carving. Consequently, there has been an unprecedented depletion of the stock of the tree species used for carving.

Okra (2012) buttressed Dei (1990) point that "woodcarving industry has thus become a key player in the deforestation of Ghana". Wood resources are depleting at a faster rate as a result of unsustainable practices in the production and marketing of the wood

products. It is also sad to note that a significant component of wood is left to waste away during production. Duku, Gu and Hagan (2011) report that wood processing waste generated in the year 2008 alone totaled one hundred and twenty eight thousand, two hundred and fifty (128,250) tones of sawn wood . In the year 1988, United Nation Development Programme/World Bank Energy Management Assistance Programme on Sawmill Residue Utilization reported that sawdust accounted for 21% of the total mill waste in Ghana (UNDP/World Bank Report 1988). All this suggest that there is much waste in the use of wood. However the waste is not put to any use.

1.2 Statement of the Problem

A cursory look at the operations of the traditional carving industry in Kumasi reveals a consistent mounting pressure on the few remaining tree species that have been used for carving since time immemorial. Some of these tree species are; Sese, Ebony, Danta, Kusia et cetera. The imbalance between demand and supply pose a bleak future for this traditional industry. As a country, we do not have the luxury of time but to act fast to salvage the collapse of this vital local industry. There is therefore the need to find a workable and action driven solution to the problem.

The many wood processing firms in this country cause so much waste that we do not have the capacity to dispose of them at the moment. Factoring in the importance of the existence of the wood carving industry as well as ensuring environmental sustainability, this project sought to reuse these wood wastes to manufacture boards that could be used for carving.

1.3 Aim of the study

The aim of this study was to assess the use of sawdust as a substitute for carving material.

1.4 Objectives

To be able to do this, the following specific objectives were looked at

1. To assess the utilization of manufactured boards as substitutes for carving.
2. To assess the factors that influence timber species selection for Wood carving works.
3. To produce and carve designed pieces out of sawdust boards.
4. To compare the quality of carved pieces from sawdust boards to that of conventional timber.

1.5 Research Questions

1. Are manufacture boards used for carving works?
2. What are the factors that influence timber species selection for Wood carving?
3. Can manufacture boards be used for carving works?
4. What is the quality of the carved pieces to that of conversional wood?

1.6 Significance of the Study

- The study will introduce an equally suitable carving material produced out of wood waste to carvers and sculpture students.
- The study will serve as a reference material for carving students, practicing carvers, researchers, and art educators in Ghana.
- It will also serve as inspiration for others to research into other alternative materials for sculpture from other waste products.
- Wood Carvers will get alternative material to work with.

1.7 Limitations of the Study

There was reluctance of some key informants to provide certain information which was assumed to be a result of their limited understanding of the research topic or weakness found in the study area. It is usually known that most people do not like to disclose their weak side. Some few informants did not have enough time to fill the questionnaire; in that case, the researcher was obliged to interview them and complete the questionnaire in their presence. Some respondents tried to give wrong information in order to cover their weakness for example, lack of some important facilities. To minimize the limitation of inadequate understanding of the topic the researcher explains to the respondents what the research is all about and also to control the problem of fear of disclosing the weak points of their work, the researcher assured respondents of anonymity.

1.8 Delimitation of the Study

Although the challenges facing the sawmill industries on standard of occupational health and safety practices is country wide, the focus of the study has been limited to Sokoban Wood Village in Kumasi metropolis alone, on the assumption that it is the area where wood processing activities are more concentrated.

1.9 Organization of the Study

This research has been organized in five chapters. Chapter one deals with the background to the study, statement to the problem, objectives of the study, research questions, significance of the study, scope of the research, limitations and organization of the study. Chapter two focuses on the review of related literature while the methodology of the study is the subject of chapter three. The chapter three presents the methods and procedures employed to collect data for the study. It covers the study area,

research design, the population, sample and sampling techniques, data collection instrument, validity and reliability, data collection procedures, and data analysis techniques. In chapter four, presentation, analysis and discussion of results are presented. Finally, the summary of findings, conclusions, recommendations and suggestions for further research are catered for by chapter five.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Wood

Wood is a complex and highly variable tissue material made of successive stacking of growth rings year after year (Pilate, 2014). Dinwoodie (2019) on the other hand saw wood as a heterogeneous material with varying strength properties example Wawa (Triplochiton scleroxylon), Wataapuo (Cola Gigantes), Ceiba (Ceiba pentandra) and Teak (Tectona grandis), Mansonia (Mansonia altissima), Danta (Nesogordonia papaverifera) and Mahogany (Khaya ivorensis).

2.2 Timber Species Available on the Markets

According to a study conducted by Oteng-Amoako (2018) out of thirty-two species that were outlined in a questionnaire, twenty-two of the timber species were found to be available on the markets. This was arrived at from the species that obtained fifty percent and above for 'Yes' response to the species. Table 1 indicates the species and their utilization as recommended Oteng-Amoako (2018) and Ametsistsi et al. (2009).

Table 2.1: Timber Species on the two local timber markets and their recommended utilization

No.	Local Name	Botanical Name	Utilization (Oteng- Amoako , 2018; Ametsistsi et al. 2019)
1	African Mahogany	Khaya ivorensis	Boat construction, cabinet works, carvings, doors, frames, furniture, joinery, flooring, etc.
2	Edinam	Entandrophragma angolense	Cabinet works, boat construction, doors, flooring, furniture, joinery, panelling, etc
3	Sapele	Entandrophragma cylindricum	Block board, carvings, boat construction, doors, fittings, frames, furniture, cabinet works, joinery, veneer, etc.
4	Emire	Terminalia ivorensis	Flooring, frames, furniture, joinery, mouldings, weather boards, shingles, doors, etc.
5	Wawa	Triplochiton scleroxylon	Block board, furniture –utility, plywood, toys, woodware, mouldings, cabinet works, etc.
6	Ceiba	Ceiba pentandra	Boxes, food containers, veneer for plywood, mouldings, etc
7	Otie	Pycnanthus	Boxes, furniture, plywood, , boat

		angolensis	construction, frames, weather board, canoe, etc.
8	Dahoma	Piptadenia africana	Garden furniture, marine defence, mining timbers, truck bodies, sleepers, joinery, etc
9	Essia	Petersia africana	Carpentry, construction –utility, sleepers, deckings, truck bodies, etc
10	Teak	Tectona grandis	Boat construction, cabinet works, flooring, frames, garden furniture, etc
11	Avodire	Turreanthus africanus	Fittings, furniture, veneer, plywood, mouldings, panellings, etc
12	Ofram	Terminalia superba	Block board, furniture, plywood, joinery, claddings, veneer, etc
13	Odum	Milicia excelsa	Boat construction, cabinet works, flooring, frames, garden furniture, joinery, etc
14	Danta	Nesogordonia papaverifera	Bench tops, boat components, cabinet works, joinery, frames, decorative furniture, etc
15	Denya	Cylicodiscus gabunensis	Bridges, construction –heavy, flooring–heavy duty, truck bodies, boat building, etc.

16	Kusia	Nauclea diderrichii	Boat construction, flooring, panelling, bridges, sleepers, vehicle and truck bodies, etc.
17	Mansonia	Mansonia altissima	Cabinet works, flooring, joinery, veneer, claddings, high value furniture, etc
18	Kyenkyen	Antiaris toxicaria	Boxes, carvings, plywood, toys, veneer, handicrafts, claddings, mouldings, etc
19	Esa	Celtis mildbraedii	Boxes, pallets, handicrafts, core veneer, etc.
20	Asanfena	Aningeria spp.	Trim, veneer, panelling, frames, joinery, furniture, luxury cabinet works, etc
21	Fotie	Hannoa klaineana	Match boxes, containers, common furniture, handicrafts, packing cases, etc
22	Hyedua	Guibourtia ehie	Cabinet works, carvings, fittings, flooring, joinery, frames, veneer, etc

From the many timber species available in Ghana, only few species were found on the market for possible utilization. This confirms the assertion that the usage of timber in Ghana is highly selective in nature and dominated by a small number of preferred timbers (Ayarkwa, 2018). Increased utilization of a wide number of species, especially

lesser-used species (LUS) may help prevent creaming for the few traditional high value species. Apparently because the properties and uses of LUS are unknown to consumers, most of them are reluctant to purchase them. The rate of growing scarcity of desirable and high value species is necessitating substitution of the high value species for LUS. Seven of the species in Table 2.1 (Kyenkyen, Ceiba, Esa, Denya, Hyedua, Essia and Otie) are LUS under promotion for their possible adoption as they were found in commercial quantities in Ghana's forest reserves and have not been subjected to any serious levels of exploitation (ITTO, 2012). All wood products are subject to substitution, especially framing materials, windows and doors, mouldings and casework, cladding, furniture, pallets and packaging (Paluš et al., 2012).

The study shows that, Mahogany (95.1%), Wawa (94.2%), Ofram (93.2%) and Asanfena (92.2%) had high response rate and assumed to be species that are mostly patronized. All the three categories of respondents seem to have knowledge on these species as they are popular and their utilization well known. Essia (59.2%), Fotie (56.9%), Odum (54%) and Avodire (53.5%) were at the bottom of the ranking of the species available.

Although these species were available, some of them like Odum and Avodire were not easily obtained by the lumber brokers to be sold on the markets. However, their presence can be attributed to their primary nature and the knowledge on the utilization of the species as well as the purpose for which the species are purchased. In the middle range were Danta (85.4%), Emire (84.5%), Sapele (83.5%), Denya (81.6%), Mansonia (79.6%), Dahoma (77.7%), Chenchen (76.7%), Edinam (75.7%), Otie (68%), Esa (67%), Hyedua (63.1%), Ceiba (63.1%) and Teak (61.2%) all received good responses of their availability.

The trend of availability of the species on the markets can be attributed to the knowledge on the utilization of the species and the easiness to obtain by the dealers. With the many wood species and different timbers available, selecting timber is not an easy task as it seems to be and selecting the right material is a very important factor (Adebara et al, 2014). Wood specifies and users usually request for only the traditional species which has resulted in over-utilization of the preferred species (Ayarkwa, 2018). Consumer preferences are permanently changing because of product innovations and changing life style of consumers (Paluš et al, 2012) and as prices of these traditional timber increase, and quality and quantities decline, manufacturers and producers have little option other than to pay attention to the lesser-known species that were previously ignored if they are to remain in business (Effah et al, 2013). The use of non-traditional tree species is also a positive move towards sustainable utilization of forests since it provides an avenue for increasing the diversity and volume of prime timbers for utilization (Zziwa et al, 2016). Unfortunately, at present only about 7% of trees in the tropical forests of Ghana are being exploited (ITTO, 2012)

2.3 Factors that Influence Species Selection

According to a study conducted by Oteng-Amoako (2018) results from the analysis indicate that all the twelve factors that were put up for consideration with regards to their influence to the selection of the species, all of them were influential towards the selection of a particular species for usage. However, durability, appearance, quality and processability were the most influential in that order. Affordability, area of usage and informed decision were the least influential factors. Type of product, expert advice, suitability, sustainability and availability were the other influential factors.

The study depicts mean ratings of factors that influence the selection of timber for furniture and joinery products at the two timber markets. Wood as building material

will be used because of its durability and other mechanical and physical properties (Paluš et al, 2012).

The reluctance to use a great variety of timbers, especially the lesser-used species, may be attributed to several factors among which are: traditional marketing practice, lack of guidance on selection for a purpose, familiar species and risk involved (Ayarkwa, 2018). Making informed and responsible choices when selecting and purchasing wood for use is one of the most important things one needs to do to get value for the money spent. Preferences are typical for consumer markets. They influence what consumers would buy and relate to the material used for product production, its quality, appearance and functionality (Paluš et al, 2012).

Although all the factors were of significant importance in the specification and selection of the timber species, factors like appearance, price and availability were all influential as the case of Zziwa et al. (2019). Durability was ranked as the most influential factor amongst all the factors. A probable interpretation is due to knowledge on the maintenance incurred on inferior species when used for certain purposes. Ranking order of the factors seems to indicate consumers' preparedness to spend more money and get value in the long run. Another reason for the price being last could be the relatively cheaper (20-40% cheaper) illegal chain-saw lumber supplied to the markets (Oteng -Amoako et al, 2018).

This cheaper price of domestic illegal lumber does not motivate producers of legal lumber to sell on the domestic market (Oteng-Amoako et al, 2018). Type of product, expert advice, suitability, sustainability, availability, area of usage and informed decision which are all very important factors for the specification and selection of

timber species for furniture and joinery production faired considerably influential from the study.

2.4 The Strength of Wood

Wood formation and development could also be regulated environmentally (Pilate, 2014). Dinwoodie (2019) also defined wood as a heterogeneous material with varying strength properties. He states that strength properties of wood generally increase from the top to the base of a tree. Mellerowicz (2011) revealed wood formation as basically a cyclic activity of the cambium. On the other hand, Winandy (2014) described wood as a homogeneous mass with multi-layered cell structure. Winandy further explains that individual cells of wood are made up of four distinct cell wall layers. Winandy elaborates that these individual wood layers are composed of three chemical polymers namely: cellulose, hemicellulose and lignin. Even though the chemical properties have much to do with wood formation, the physical make up also contributes to both thermal and mechanical strength of wood. Physical properties are the quantitative characteristics of wood and its behavior to external influences other than applied force. Properties like directional, moisture content, dimensional stability, thermal; pyrolytic and decay resistance properties could significantly affect the performance and strength of wood. This means that although wood grows naturally, its strength can be consciously enhanced environmentally (Winandy, 2014).

Wood also as a natural material has its own challenges. Society of Wood Science and Technology (2012) reported that wood shrinks or swells because of different amounts of moisture contained in radial, tangential and longitudinal directions due to its anisotropic nature. Society of Wood Science and Technology (SWST) report 2012,

further says that inconsistent moisture content causes internal stress on the parts may result in the shrinking process.

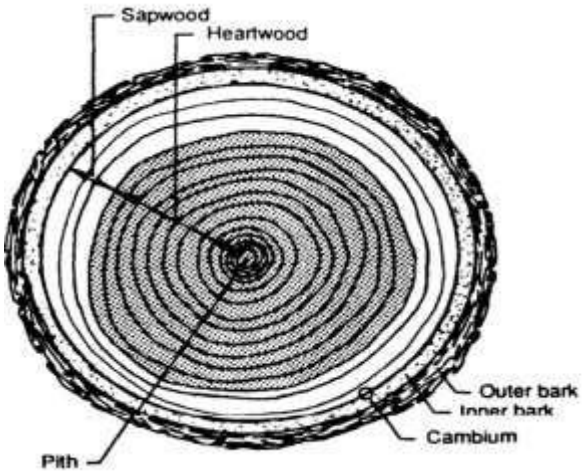

Figure 2.1: The elements of micro-structure of normally wood visible without magnification

2.5 Timber Species used for Carving

As cited in Acquah (2018), the National Forest Inventory (NFI) reports that Ghana has more than 680 wood species. Even though there are 680 wood species in Ghana, only 126 species are able to grow to the size capable to be used for all wood working purpose. This therefore indicates that more than one third of the available wood species in Ghana cannot be used commercially (Okra, 2012) According to Domson (2017), most of the wood species for the timber market are obtained from the evergreen forest in the south-western part of Ghana. Some of the prominent wood species in the evergreen forest belt are Wawa (*Triplochiton scleroxylon*), Wataapuo (*Cola Gigantes*), Ceiba (*Ceiba pentandra*) and Teak (*Tectona grandis*), Mansonia (Mansonia altissima), Danta (*Nesogordonia papaverifera*) and Mahogany (*Khaya ivorensis*).

Even though the exact varieties of wood species used for carving have not been known, Boateng (2013) states that "Varieties of tropical wood species used as raw material for carving included the following: Afromosia, Kokrodua Kyenkyen, Mahogany, Odum, Dwuma, Sese, Twenebua, Wawa, Onyina and Funtum. Different wood species may be used depending on their availability in a particular society. Amoh (2019) reiterates that "indigenous wood carver generally utilizes soft woods often in their green state which are then easier to work ". Other factors like design and the nature of the work to be produced may also be considered in choosing particular wood species. Amoh (2019) further stated that Wood such as Nyame Dua (*Alstonia boonei*) and Osese (*Holarrhena floribunda*) are the principal species used. Tweneboa (*Entanchophragma*) for drums, Twafo yeden (*Harrisonia occidentcel*) is for umbrella\frames), Funtum (*Funtumia elastica*) for stools, bowls, combs, Odee (*Okonbaka ambrevellei*) is evil tree for religious dolls and Gyenegyene (*Cedrela mexicana*) among others are the trees commonly carved Nyamedua /Sinnuro (*Alstonia boonei*) and Funtum (*Funtumia elastica*) are among the most widely used wood species for carving.

They are soft, light weight and not durable. They are promptly affected by shrinkage while drying and pests attack them easily. Amoh (2019) stated that "They are mostly used for making stools, bowls, combs, linguist staffs, Akuaba doll and totemic animal forms." Adu-Agyem (2010) described Tweneboa (*Entanchophragma*) as a hard and durable wood which is able to stand the test of time. It does not crack easily and is mainly used for making drums and jewelry boxes.

According to Okra (2013), based on workability, durability and customer demand, just a few of these many wood species available in the Ghanaian forest are traditionally preferred for carving. On the other side, timber industries in the country have specific species they deal with. Acquah (2018) stated that the International Institute of

Environmental Development (IIED) in its 1995 report estimated that Ghana's supply of most valued wood species on the world market like ; Awiemfosamins, Edinam, Koto, Mahogany *(khaya seregalensis*),Odum (*chlorophora excelsa*) emire,and kusia were predicted to drop by half within five years. On the other hand, Dei (2010) also recorded that wood species that are felled for carving are many though their exact number cannot be known. This could also be a contributing factor to the loss of the total forest cover.

2.6 Natural Durability of Wood

One key to satisfactory use of timber as a building or construction material is an understanding of agents and conditions that can lead to its decay or other forms of deterioration (Haygreen and Bowyer, 2016). The natural durability of the LUS needs to be determined from in situ tests to enable it to be used appropriately; this can be done using field trial tests or graveyard tests. The natural durability of wood is its ability to resist the attacks of foreign organisms including fungi, insects and marine borers (Panshin and De Zeeuw, 2010).

A number of factors account for the natural durability of wood. These include the presence of extractives, and moisture content outside of the natural moisture limits of the agent of destruction. Other factors may also complicate assessments of natural durability. Individual trees of the same species may also differ considerably in their decay resistance. Observed differences may be due to genetic factors (Scheffer and Hopp, 2019) and possibly to silvicultural systems (Edmonson, 2017). Campbell and Clark (2010) reported on correlation between locality and durability.

Edmonson (2017), reported that Australian natural grown *Syncarpia laurifolia* (turpentine wood) was quiet resistant to the marine borers *Teredo* and *Limnoria* while plantation-grown *S. laurifolia* grown in Hawaii was rapidly attacked. Wood consists of

sapwood and heartwood. The sapwood is constituted by a part of living cells and conducts water and mineral salts. It is frequently attacked by insects due to the presence of soluble reserve food substances in the parenchyma cells. These stored carbohydrates which serve as nutrient sources can be a factor promoting attack by fungi and insects. The sapwood undergoes a number of changes to be transformed progressively into the heartwood. Some of the changes are: increase in acidity, formation of extractives such as tannins, which gives it a specific color and formation of gums, resins, tyloses and usually decrease in moisture content. These transformations and processes may render the heartwood more durable than the sapwood and sometimes slightly harder. The presence of these extractives in sufficient amounts prevents or minimizes the severity of attack by destructive organisms if the extractives are toxic or repellent. The toxic substances vary from species to species and in their chemical properties so that different solvent systems will effectively extract different toxins in different species (Eaton and Hale, 2013).

An indication of the effect of extractives on the durability of heartwood in some species is the early decomposition of the extractive-free sapwood from a piece of lumber. In some instances, the lower resistance of sapwood may be due to its greater permeability (Kollman and Cote, 1984). Moisture content below fiber saturation point prevents or minimizes the attack by some organisms, particularly the decay fungi, because they need sufficient and easily available moisture to facilitate metabolism. Furthermore, the heartwood's lower rate of diffusion, the blocking of cell cavities by gums, resins, tyloses in the vessels and tylosoids in the resin canals adversely affect the balance between air and water necessary for the growth of fungi (Kollman & Cote, 1984).

The natural resistances of wood to deterioration that can be ascribed to reasons other than the toxicity of its extractive substances are the woody cell walls. These consist of

highly complex, insoluble polymers of high molecular weight; these substances must be altered by enzymes produced by the attacking organisms into simpler products before they can be assimilated. Wood lignification creates a physical barrier to enzymatic attack on the polysaccharides.

Therefore, only those organisms that possess enzymes capable of destroying the lignin or at least of altering its protective association with the polysaccharides are capable of decaying wood. The structure of cellulose with crystalline and amorphous regions also restricts the action of depolymerizing enzymes. They can initially only affect the non-crystalline portions. Therefore, cellulose can sometimes provide some resistance to fungal and bacterial degradation.

Durability of wood varies within and between trees. Variation within a tree is particularly so especially in species with very durable heartwood. In a wide-ranging review on natural resistance, Scheffer and Cowling (2016) summarized the following general points. In many species inner heartwood is less durable from the base of the tree upward, while the opposite occurs with outer heartwood. At the base of the tree these differences are most extreme; further up the tree the resistance is intermediate. The larger the tree the greater is the differences at the base.

Although no known wood is entirely immune to the attack by degrading organisms, a number of wood species possess superior resistance. It must be kept in mind; however, that timber resistant to fungal attack may or may not be durable when subjected to attack by insects or marine borers. Furthermore, the durability of a given wood species may fluctuate between wide extremes (Kollman & Cote, 1984).

2.7 Wood Waste

Wood waste potential depends on many factors, its next processing is mainly depended on the high volubility and possible content of harmful substances. The estimation of the waste wood statistics in the EU is provided basically on a) wood waste from municipal waste b) construction and demolition wood, and c) waste wood from industry (by products). In 2018 European Commission published the 206 wood research Guidance on cascading use of biomass with selected good practice examples on woody biomass. The Circular Economy Action Plan adopted in 2015 aims to turn Europe's economy into a more sustainable economy, promoting sustainable economic growth and generating new jobs. The actions in the plan seek to close the life-cycle loop of products and materials by keeping their value in the economy if possible, minimizing the generation of waste and maximizing recycling and reuse. These benefits both the environment and the economy. Although the idea of wood waste recycling has only begun to become more serious in recent decades, researchers have been dealing with the issue of wood recycling in the past. But practical application in industry has been progressively and over time, considering more economic (Zeng et al. 2018) as environmental benefits (Michanickl 1996). The European wood-based panel industry relies primarily on the softwood timber supply, so waste wood and recovered wood assortments are becoming more important (Janiszewska et al. 2015, Meinlschmidt 2016). Recovered waste wood particles can be used for production of eco-friendly wood composite materials bonded by bio-based adhesives (Antov et al. 2020). Recycling of wood waste is difficult due to a content of harmful chemicals contained both in glue used during a manufacture process (Risholm-Sundman and Vestin 2005) and in additives which originally served to protect it from moisture content, wood decaying fungi, to increase fire

resistance and so on (Erbreich 2004). Different authors have used different techniques to determine the content of chemicals contained in waste wood, as for example, laser-induced breakdown spectroscopy (Uhl et al. 2001). Moskal and Haln (2002) suggested the online detector system using laser-induced breakdown spectroscopy for the analysis of copper chromated arsenate (CCA) treated wood products from the waste stream at a construction and demolition debris recycling center. Accuracy of handheld XRF analyzers on wood that has been treated with a preservative containing arsenic was determined by Block et al. (2007). Concentrations of wood preservatives in the wood chips produced in wood-waste processing facilities around 2000 in Japan was investigated by Kurata et al. (2005). Concentration levels depended on the sources of the wood wastes. Methods of recycling the wood particles from waste wood-based materials were suggested previously by Michanickl and Boehme (1996). Several authors had been devoted to issue of a further processing of large-scale wood-based materials (Riddiough and Kearley 2001, Riddiough 2002). There are many opportunities for composites made from recycled wood-based waste resources. Research in these areas could result in a new product range in combination with other materials that are cost effective, designed to meet demands of end-use, and environmentally friendly (Boehme 2003, Wolff and Siempelkamp 2000, Rowell et al. 1993). Review studies of wood waste carried out after 2000, several studies were conducted that dealt with wood in the form of waste or use of wood residues. Several review studies that directly or partially (Jeffrey 2011) deal with waste wood have been published. Tam V. and Tam C. (2006) published a study related to the technology on the construction waste recycling and their viability. Timber recycling technology has been also considered, as well as other materials suitable for recycling (asphalt, brick, concrete, ferrous

metal, glass, masonry, non-ferrous metal, paper and cardboard and plastic). Kartal and Imamura (2003) published a review on chemical and biological remediation's of CCA-treated (chromium, copper, and arsenic) waste wood. Chemical extraction using inorganic and organic acids and bioremediation using bacteria and fungi were summarized. Several alternative methods for the disposal of CCA treated wood waste have been published also by Helsen and Van den Bulck (2005). Alternative disposal methods include recycling and recovery, chemical 207 Vol. 65 (2): 2020 extraction, bioremediation, electro dialytic remediation and thermal destruction. Dias et al. (2007) determined waste wood as one of precursors of activated carbon (AC), which is a preferred adsorbent for the removal of micro pollutants from the aqueous phase. AC can be prepared from conventional waste from wood industry to remove organic pollutants, dyes, volatile organic compounds, and heavy metals. Required high surface areas can be obtained using either physical or chemical activation. The main reason to build this review study was to describe attitudes of different researchers to a waste wood processing in points of selection according to its origin and according to products made of it, sorting the industrially applicable implementations in large scale as well. Source of wood waste many studies solve a problem of accumulation of waste in the place of its origin. Usually large amounts of this waste end up in dumps every day with the highest environmental impacts (Di Maria et al. 2018). Authors distinguish municipal wood waste from land fields (Stahl et al. 2002), wood waste from construction site (Wang et al. 2016, 2017), demolition waste (Asari et al. 2004, Huang et al. 2002, Rautkoski et al. 2016), and wood industrial waste (Ahmed et al. 1998), also closely specified by type, f. e. hardwood residue (Shulga et al. 2014), untraditional softwood residue (Ozaki et al. 2005, Al Maadeed et al. 2014), or used railway sleepers (Ashori et al. 2012). Some atypical

solutions are mentioned as well, as pruning residuals in olive groves and vineyards (Recchia et al. 2009). The bark is not a typical wood waste but since it is produced in parallel as byproduct from sawmills many authors are concerned with this issue, not preferring its direct energy use (Andres et al. 2010, Ghitescu et al. 2015, Medveď et al. 2019, Mirski et al. 2020). Generally, bark has often had three main uses: an animal bedding, an energy recovery and a mulching (in gardening and landscaping). These are generally low values uses. A great source of wood waste are agglomerated materials as particle boards (PB) mainly from old furniture (Ihnát et al. 2017, 2018, Balberčák et al. 2017, 2018, Wan et al. 2014), oriented strand boards (OSB) (Schoo et al. 2003, Wan et al. 2014, Ihnát et al. 2017, 2018, Zeng et al. 2018), and middle density fiberboards (MDF) (Wan et al. 2014, Ihnát et al. 2018, Petar and Savov 2019). Size reduction and wood waste down cycling Regarding to the wood waste processing in the terms of sequence: reduce-reuse-recycle (Falk 1997), a cascading utilization of resources is encouraged (Höglmeier et al. 2014). Basically, wood recycling is almost always associated with the disintegration (size reduction) of bulk wood waste into small particles (chips, fiber, etc.,) which are reused to produce composite materials (Ihnát et al. 2015). The particles obtained have mostly reduced mechanical and other properties (Buyuksari et al. 2010) and therefore added just in certain proportions (Chen et al.2006). The process whereby a product is recycled to obtain a new product with a lower added value (technical or utility) is called downcycling and is a frequent phenomenon in the processing of waste wood. Upcycling of this waste material group is unique (Meinlschmidt and Mauruschat 2015, Russ et al. 2013) and almost impossible to apply in a mass production. Methods of the size reduced particles treatment Attention was focused on methods of removing chemical loads from waste wood. Kabir et al. (2006) found out that

most of the CCA components could be extracted by 10% H2O at 50°C in 6 hours with an average extraction efficiency of 95% for Cr, 94% for Cu and 98% for As. The extract containing Cr3, Cu2 and AsV could be oxidized in several stages by aqueous 2.5% 208 Wood Research W/W H2O in less than 2 h. Shupe et al. (2006) used steam treatment to remove residual creosote content of sawdust obtained from weathered, out-of-service poles. Steaming was successful in reducing the creosote content to a level of 1.31%. Hse et al. (2013) provided a recovery of metals from CCA treated southern pine wood particles by the extraction in a microwave reactor with the binary combinations of an acetic acid and phosphoric acid. The highest recovery rate of metals achieved with a mixture of 2.75% phosphoric acid and 0.5% AA at 130°C in 10 min in the microwave oven. Special attention has been paid to recycling of panelboards. In generally, three different principles can be applied for disintegration of panelboards: mechanical, thermo-hydrolytic and chemical, or combinations thereof (Kharazipour and Kües 2007). These processes were mostly described before 2000 and improved or novelized later. Fleischer and Marutzky (2000) were addressed to degradation of glued UF joints in waste particleboards. Lykidis and Grigoriou (2008) provided four different hydrothermal treatments applied in order to recover wood particles from waste particleboards and use them in the production of new (recycled) ones. It was found that other recycling cycles caused the deterioration in the quality of the recycled boards as regards their mechanical properties. Lykidis and Grygoriou (2011) concluded that the optimum hydrothermal recovery parameters were 45% water retention, 150°C temperature, and 10 min duration. Roffael and Hüster (2012) provided thermos hydrolytic treatment of chips from waste UF-bonded particleboards using the flask method at 103°C for the reaction period of 24 h due to degradation of the UF-resin. Wan et al.

2014 subjected medium density fiberboard (MDF), particleboard (PB), and oriented strand board (OSB) panels to steam explosion treatment. Downgraded panels were treated with thermal chemical impregnation using 0.5% butane tetra carboxylic acid (BTCA) to disintegrate UF bonds and were processed with mechanical hammer milling. The hammer milling of recycled PB was less likely to break particles down into sizes less than 1 mm2. Moezzipour et al. (2017) investigated the changes in the chemical properties of wood fibers after hydrothermal recycling of MDF wastes as an important aspect of recycling process which may be efficient on quality of recycled MDF boards. Hydrothermal recycling was done at different temperature (105, 125 and 150°C) in which subsequently defibrillation step was performed. Recycling of heavily contaminated wood Recycling of CCA, or creosote-protected products forms a separate category of recycling due to classification as hazardous waste (Humar et al. 2011). Also, common disposal of wood treated with the chromated copper borate (CCB) due to toxic elements (Cu, Cr, and B) is not considered as environmentally sound solutions (Humar et al. 2004). Mengeloglu and Gardner (2000) evaluated flake boards produced from recycled CCA treated and untreated southern pine (Pinus spp.) using two adhesives (polymeric methylene diphenyl diisocyanate and liquid phenol formaldehyde) and two common flaking techniques (ring and disc flakes). Clausen et al. (2001) remediated CCA-treated southern yellow pine chips utilizing acid extraction alone and using acid extraction followed by bioleaching with the metal-tolerant bacterium Bacillus licheniformis. Chips were used to make particleboard with 10 percent urea-formaldehyde resin. Reduction of the strength properties was observed. Kartal and Clausen (2001) evaluated the effect of remediation processes with oxalic acid (OA) extraction and Bacillus licheniformis fermentation, on leaching of copper, chromium, and arsenic

from particleboards made from remediated wood particles. The particleboard containing OA-extracted and bio remediated particles showed generally high leaching losses of remaining elements. Exposure of particleboards to decay fungi in soil block tests indicated that boards containing CCA-treated particles were most resistant to fungal degradation. Zhou and Kamdem (2002) investigated effect of Portland cement/ particles 209 Vol. 65 (2): 2020 from CCA treated red pine ratio on properties of result products and this was determined as a ratio of 3. Catallo and Shupe (2003) described the treatment of 15 years old creosote-treated pine utility pole wood in an anoxic supercritical water. The creosote-derived hydrocarbon residues in the chipped wood were nearly completely recovered, and the wood itself was transformed into a mixture of hydrocarbons including substituted benzenes, phenolics, and light PAHs. Kamdem et al. 2004 studied the feasibility of using recycled plastic and wood particles from CCA-treated wood removed from service. CCA pressure-treated red pine lumber removed from service after 21 years utilization was milled to the wood flour and blended with virgin or recycled high density polyethylene at 50:50 wood floor-to-plastic weight ratio. Effects of different ratios of recycled CCA-treated wood and untreated virgin wood on flake board properties were compared by Li et al. (2004). Clausen et al. (2006) fabricated particleboard and flake board panels from remediated CCA-treated southern yellow pine. Treated wood, flaked or comminuted into particles, was remediated using oxalic acid extraction, followed by bioleaching with the metal tolerant bacterium Bacillus licheniformis in trial experiment. Remediation resulted in removal of 80% Cu, 71% Cr, and 89% as for the particulate material and 83%Cu, 86%Cr, and 95% as for the flaked material. New down cycled wood waste products New value added (technical or economical) of new products made of wood particles treated from waste

wood is a measure of a sufficiency of its down cycling. Second generation biofuels made from waste wood (Okuda et al. 2008, Shi et al. 2009) are considered for future industrial production with a high potential. Secondary down cycling was provided, the possibility to utilize fiber sludge, waste fibers from pulp mills for combined production of liquid biofuel was investigated by Cavka et al. (2011). Laboratory production of ethanol from sawdust was provided by Chen et al. (2017), also by Afzal et al. (2018). In 2016 the first industrial-scale production of its kind in the world has been launched in Finland. Different pretreatment methods had been studied as a dilute acid pre-treatment on wood dust (Akhabue et al. 2019) or steam explosion on wood particles from waste boards (Pažitný 2019). Iakovlev et al. (2020) used two grades of recycled wood to fractionate on a pilot scale) the monomeric sugars, lignin and lignosulfonates using SO2-Ethanol-Water (AVAP®) technology, including pretreatment, separation of cellulosic and hemi cellulosic streams, and scarification. Different example of waste wood down cycling was shown by Bekhta et al. (2019), who examined lignocellulosic waste fibers obtained from fiberboard wet process, recycled paper process, and cellulose process as adhesive additives on some physical and mechanical properties and formaldehyde emission of adhesives and plywood panels. Reduction of formaldehyde emissions by up to 27.8, 24.9, and 19.4%, respectively compared with control panels was achieved. The shear strength of plywood panels with all investigated sludge's met the requirements of the EN 314-2 standard. Janiszewska et al. (2016) liquefied mixed hardwood-softwood powder and bark and tested as binders for particleboards made of recycled wood. The liquefaction reaction was carried out with a mixture of solvents from poly hydroxyl alcohols and p-toluene sulfonic acid as a catalyst. Then the liquefied waste from woods were characterized production as a partial substitute for synthetic urea-

formaldehyde resin. It was demonstrated that the substitution of UF resin up to 20% did not have a significant effect on the mechanical properties. Li et al. 2020 produced polyhydroxyalkanoate (PHA) via mixed a microbial consortia as a green alternative to replace the traditional petroleum-based polymers. Authors synthesized PHA using a volatile fatty acids (VFAs) obtained from the co-fermentation of pretreated wood waste 210 wood research and sewage as carbon source. High PHA yield of 0.71 g COD PHA/g COD VFAs and PHA content of 50.3 g PHA/100 g VSS were obtained at VFAs ratio (even:odd) of 88:12 after seven cycles cultivation. Also, biochar may be stated in this review in a different position as wooden pellets and briquettes directly intended for combustion. As biochar understood as high-value, climate friendly soil improvement material made from woody biomass. When used in soil, biochar reduces the need to use energy-intensive soil fertilizers, since it provides excellent nutrients for plants in the right form and can also substitute peat as a growth and water-retaining medium. Biochar is a product made via pyrolysis or Torre faction, means a process where waste wood is exposed to high temperature and oxygen deficiency (Yargicoglu et al. 2015). Wood waste may be a bit an interesting source of raw material for pulp and paper industry as well. But environmental aspects would have to outnumber the economic ones. Kraft pulp from industrial wood waste was evaluated and compared with softwood and hardwood pulp by Ahmed et al. (1998). Pulp bleach ability was also evaluated. Compared to loblolly pine pulp, industrial wood waste pulp needed less cooking time to achieve the same kappa number and achieved a higher pulp yield for a similar kappa number. Balberčák et al. (2017) described a method of the evaluation and preparation of fluting liners produced from semi chemical pulp made of waste wood particleboards and oriented strand boards (OSB). Combination with old corrugated cardboards (OCC) used to

improve their strength properties. The semi chemical pulp was obtained by a mildly alkaline boiling process. Properties as thickness, bulk density, Gurley, tensile strength, tensile index, breaking length, burst index, CMT30 and SCT were monitored on lab sheets 127 g. m-2 and 170 g. m-2. Values of pH and residual NaOH and Na2CO3 were determined in batch leachate. In the next study (Balberčák et al. 2018) authors described an alkaline cooking process from a sorted fraction of the 4-8 mm chips obtained from same waste sources. Pulp industry uses recycling in broad range. Virgin southern pine fibers and recycled old corrugated cardboard (OCC) were used to produce fiberboards. The virgin fiber was generated using a Kraft process (Hwang et al. 2005). Bending properties and dimensional stability were linearly dependent on virgin fiber ratios. Authors note that all panels with recycled fiber content greater than 40% failed to meet any commercial requirement. Irle et al. (2019) aimed to generate high-value products from recovered wood to achieve even higher rates of wood recycling. Authors described the extraction of nano-crystalline cellulose from waste MDF and produced laminated beams from recovered wood. But even though a cases mentioned above the down cycling of wood waste is most economically advantageous for the production of composite materials. For this reason, we will describe in detail the research carried out in the areas of production: particles boards, fiberboards, wood –plastic and cement-bonded composites: Particleboards (PB) Wang et al. (2007) manufactured a low formaldehyde emission particleboard from recycled wood waste chips using polymeric 4,4′ methylene-diphenyl isocyanate (PMDI) and phenol-formaldehyde (PF) resins for use in indoor environments. The results showed that the formaldehyde emission released decreased linearly with increasing PMDI/PF particle ratio linearly. It was found that the increasing of PMDI/PF particle ratio positive influences on bending strength,

internal bonding strength and screw holding. Ihnát et al. (2017) described a method of the particles preparation from waste particleboards (chipboards) and oriented strand boards (OSB). Method of the waste boards destruction, depending on the glue base urea formaldehyde (UF) or melamine-urea formaldehyde (MUF), further processing and final particle characterization were determined. Merrild and Christensen 2009 showed that the greenhouse gas emissions (GHG) related to upstream activities (5 - 41 kg CO2 equivalents to one tonne of wood waste) are negligible compared to the downstream processing (560 - 120 kg). Savings in GHG emissions downstream are mainly related to savings in energy consumption for drying of fresh wood for particleboard production. Merrild & Christensen (2009) issued a potentially large downstream GHG emissions savings, which can be achieved by recycling of waste wood (1.3 - 1.9 tonnes). However, the GHG account highly depends on the choices made in the modelling of the downstream system. Kim and Song (2014) quantified the environmental impacts per tonne of wood wastes. The results showed that the particleboard from wood wastes produces 428 kg CO2 eq compared to particleboard from fresh woods. Fiberboards (MDF) Recycled fiber material might be further used in paper making or in fibre board production (Dix et al. 2001), although it is dark and not as sufficient as other pulps. Mantanis et al. (2004) described a process based on refiner techniques and allows the use of mixtures of fresh wood and waste panel chips as a raw material for dry-process fiberboard production. Testing results revealed that under conventional gluing and pressing conditions, the process effectively recycles the waste boards at a wood substitution level of at least 25%.

Ju and Roh (2017) used recycling wood fiber from waste MDF for the manufacturing of interior decorative accessories. Coloristic analyze was provided on fibers dyed by

using different reactive dyes. The recycling fiber looked a little darker than the virgin fiber, also the recycling fiber showed a little higher values of color yields. Ihnát et al. (2018) described a process for the preparation of fibre from waste wood particleboards, oriented strand chipboard and medium density fibre board (MDF). The obtained wood particles were characterized by the fractional composition of chips and subsequently mechanically defibred with subsequent characterization of fiber obtained for its reuse in the manufacture of MDF. A quantity of formaldehyde released into the water when cooking waste MDF and PB was set up depending on the cooking time. Lubis et al. 2018 studied the effect of recycled fiber content on the recycling properties of MDF. Statistical analysis indicates that the minimum of 10% recycle fibers can be used without diminishing the properties of recycled MDF. Fiber length of the recycled fibers obtain from recycled MDF is about 12% shorter than that of the virgin fibers and the percentage of shorter fibers is higher (≤0.68 mm) for the former than the latter (Zeng et al. 2018). Wood –plastic composites To reduce the energy input for residue milling for obtaining a lignocellulosic filler as well as to activate its surface for the further modification, the optimal parameters of low temperature acid hydrolysis of the hardwood residue under mild conditions were used (Shulga et al. 2014). Recycling wood and plastic waste into wood-plastic composites (WPCs) was discussed by Wang et al. (2017). Flexural strength, thickness swelling, water absorption and thermal insulation were observed. Melamine resin was adopted for impregnating anti-microbial agents on the surface. Poly-diallyl-dimethyl-ammonium chloride and silver were used as well. All the agents showed excellent bactericidal rate against to the Escherichia coli. In terms of weight loss and strength reduction due to fungal decay (Coriolus versicolor), poly diallyldimethylamm onium chloride, silver and cetyltrimethylammonium bromide

(CTAB) provided the highest resistance. Copper provided the most protection against an algal growth (Chlorella vulgaris). Lyutyy et al. (2017) determined the release of formaldehyde, phenol, and ammonia from flat pressed WPC obtained from recycled polyethylene and wood particles by chamber method in a laboratory scale. It was found that formaldehyde, phenol and ammonia emission of flat pressed WPC are much lower than steady-state emission. 212 wood research Cement-bonded particleboards Some authors prefer cement composite materials that are a significant solution to the problem lignocellulosic wastes, generated worldwide, from various sources such as agriculture, construction, wood and furniture industries leading to environmental concerns. However, in this effort there are various restraints like compatibility of these wastes with cement, their toxicity, and limited composite strength (Karade 2010). Bao et al. (2001) used charcoal obtained from wood based waste materials to determine the properties of charcoal-cement composite boards. Thirteen types of mixture ratios of charcoal to cement were used to produce 10mm-thick composite boards. The flexural strength of the board showed the maximum at the charcoal/cement mix ratio of 0.05, and then decreased as the mix ratio increased. The possibility of recycling waste medium density fiberboard (MDF) into wood–cement composites was evaluated by Qi et al. (2006). New fibers and recycled steam exploded MDF fibers had poor compatibility with cement so a rapid hardening process with carbon dioxide injection was adopted. After 3–5 min of carbon dioxide injection, the composites reached 22–27% of total carbonation and developed 50–70% of their final (28-day) strength.

2.8 Sawdust

Marfo (2010) defined wood waste as any wood that has no longer any value at its present location. In this regard, wood waste could therefore come about as offcuts,

shavings, mill residue and sawdust through observation asserts that sawdust is classified as a wood waste. According to Marfo (2010), wood waste occurs not only during logging operations but also during secondary processing. He further, states that wood waste occurs in the forest as logging waste and occurs as mill waste in the form of sawdust, offcuts, trimmings, slabs edgings and veneer cores. Wood processing wastes such as discarded logs, bark, sawdust, off-cuts, etc., on the other hand, are generated through sawmill and plywood mill processing activities.

Duku et al, (2011) contend that, "generally, sawmills in Ghana have recovery rates ranging from 20% to 40% of the log input, averaging 33.3%". As cited in Duku et al (2011), the FAO estimated that wood processing wastes generated in the year 2008 totaled 256,000 m3, equivalent to hundred and twenty eight thousand two hundred and fifty (128,250) tones, based on sawn wood production for 2008. This assertion reveals how sawdust, a regenerative material is left to go waste (Global Forest Product facts and figures 2013).

Another report by UNDP/World Bank Energy Sector Management Assistance Project on Sawmill Residue utilization in 1988 indicated that sawdust alone accounted for 21% of the total residues generated. In this light, sawdust could also be said to be the volumes of unrecovered saw offcuts produced as a result of wood processing either in the preliminary or secondary stages. (UNDP/World Bank Report 2018). It may also be classified as one of the many kinds of residues produced after wood or timber has been economically exhausted. Offcuts as a result of wood processing activities may vary in sizes and density depending on the machine that is used in the process (Xll World forestry congress, 2013).

In this research report, sawn offcuts would be the researchers focus. Owing to varied saw blades, even this category of wood waste may be further varied according to size

of individual sawdust particles. They may range from powdery smooth to gravel coarse particles. (Australian wooden furniture manufacturing companies report November 2019). Their colour may also range from white to dark brown depending on the parent timber from which the off cut was made. Sawdust is abundantly available at saw mills and carpentry shops (Australian wooden furniture manufacturing companies report November, 2019).

2.9 Particle Board

Haygreen and Bowyer (2016) defined particleboard as a panel product produced by compressing small particles of wood whiles simultaneously bonding them with an adhesive. Particleboard is a panel product manufactured by spraying wood particles with adhesive, forming them into a mat, and compressing the mat to desired thickness between heated Platens to cure the adhesive (Hoadley, 2010). Particleboard can also be said to be a three-layered board, with fine particles on the top and bottom surfaces, and larger wood flakes in the middle. Particleboard can be said to be a generic term for a composite panel primarily composed of cellulosic materials (usually wood), generally in the form of discrete pieces or particles, as distinguished from fiber, bonded together with a bonding system, and which may contain additives.

The wood particles are pressed and bonded together with resin creating a tight compact panel that can be machined cleanly. The process of stress-transfer is complete if there is good bonding between the particles and the matrix. Coupling agents are therefore essential to ensure suitable bond formation between the particles and the matrix. Coupling agents may physically or chemically improve the bonds (Myers et al. 2011). The surfaces are sanded smooth at the mill, ready for use or

finishing with a high-pressure laminate, decorative foil or timber veneer. Particleboard is one of the two groups of particle composites which are commonly recognized based on size of wood components and the method of manufacture. Particleboards have chips, flakes, or wafers as the major constituent.

The other group of particle composites is the fiber board. It has its major constituents as fiber and fiber bundles (Bodig and Jayne, 2012). The strength of the product is determined by the adhesive used and not the fiber used, although the size and shape have influence on the strength (Kent and Riegel, 2017). Particle boards, however, offer the advantages of a homogeneous structure and the use of raw materials without restrictions as to the shape and size (Eshaghi et al. 2013). They are also more environmentally preferred due to no-added-formaldehyde in their formulations. Use of natural fibers in composites can improve mechanical properties while reducing costs and weight (Lee et al. 2011).

A study was therefore carried out to evaluate some physical and mechanical properties of cement-bonded particleboard made from pine sawdust and coconut husk (also known as coir). The latter is a residue that has been identified as a suitable substitute for wood in some applications, as it has been observed that agricultural residues provide renewable and environmentally friendly alternative biomass resources for easing the high demand for woody materials (Sampathrajan et al, 2012; Kozlowski and Helwig, 2018).

Particle board is environment friendly material, made of wood particles glued together, like wood chips, flakes, strands, sawdust, and wood shavings. They are also called chipboards or low-density fiberboards (LDF).

Engineered wood products are used to produce furniture and other wooden objects for both internal and exterior use. One of the many engineered wood products is particle

board. It's also known as chipboard or low-density fiberboard. The beautiful thing about modern woodworking is that you may choose from a variety of engineered wood components for your projects. Particleboard is one such wood product. Because it was made from wood chips coupled with synthetic resin and other binder components, particleboard is also known as chipboard. It's a waste wood product manufactured by gluing wood chips, sawdust, or sawmill shavings together with synthetic resin or another binder. The adhesive urea-formaldehyde is often used to bind wooden chips. Particleboards are made by pressing and extruding these mixed materials.

Particle board, as a product, dates from the early 20th century and developed in use during the World War II to utilise inferior wood and wood waste when good quality wood was in low supply (Stark *et a.*, 2010). Particle board is produced by reducing timber to particles, generally less than 2 mm in any dimension. These are then formed into a panel and bound together using an adhesive resin, traditionally UF or PF. Other resins can and have been used, for example, isocyanates, and there is ongoing research into utilisation of non-formaldehyde-based resins due to concerns over indoor air quality.

Many particle boards are manufactured using a layering system, where the core of the board consists of large particles and the outer layers are finer particles, allowing improved surface finish. Technology for particle board manufacture has developed so that sawdust, mill residues and recycled wood can be used. Other non-wood lignocellulose materials have also been used for particle boards, for example, bagasse (Carvajal *et al*, 2016; Xu *et al*, 2019; Monteiro de Barros Filho *et al*, 2011).

2.9.1 Manufacture

In brief (for a detailed description, see Thoemen *et a.*, 2010; Nishimura, 2015), the manufacture of particle board involves the debarking of the wood which is then cut into small chips or flakes using a 'chipper' and then subsequently further reduced in size. This secondary reduction is accomplished in a number of different ways, for example, hammer mill (grinding and crushing) or knife systems (cutting and slicing). Disc refiners may also be used to produce very fine particles, for surface finishes, via attrition. The particles are then dried before being sprayed with resin (differing resin amounts may be used for core, e.g. 6%–12%, and surface layers, e.g. 4%–8%), and a mat of chips (coarse in centre and fine on surface) is formed. The mat is then pressed, in either a continuous or batch process, at high temperature (e.g. 200°C). Finally, the boards are cut and trimmed to size and finished by sanding or by addition of any coating or lacquers or high-pressure (*HPL*) or low-pressure (*LPL*) melamine-impregnated paper laminate.

Each year, about 28.4 million m^3 of particle boards are produced in Europe mainly for furniture and building applications (Klímek *et al*, 2016). Wood is the main raw material used to this end, although the feasibility of nonwood alternatives has been investigated for many decades. Recently, many drivers, including wood shortage, environmental awareness and low cost of non-wood materials, boosted not only for an intensification of this research but also for a major implication of industries.

In 2005, at least 30 industrial plants all over the world integrated the use of non- wood lignocellulosic aggregates in the production of particle boards (Bektaş *et a.*, 2005). Today, although the technical feasibility of non-wood particle boards is generally accepted (Bajwa *et al*, 2015), further research is needed to fully understand how the intrinsic properties of the raw materials can contribute to enhance the overall

performance of the engineered materials. The vast majority of the examples of non-wood particle board developments are focused on the use of different kinds of natural fibres. This is consistent with the fact that fibres make an important contribution to the enhancement of the mechanical properties of the boards.

Fibrous_materials from crop plants are preferred for their availability and easy accessibility. Examples are straw (from wheat, barley, rice, etc.), cotton gin or bagasse, coir and kenaf or banana fibres. Some investigations have been conducted in which vegetal pith-rich plants were evaluated; however, it is rare to find examples of the use of isolated vegetal pith in the manufacture of particle boards. It is well known that particle size and shape affect the properties of the particle boards. Vegetal pith aggregates tend to form rather spherical particles, (Magniont, 2010; Palumbo, 2015, 2015).

Generally, more spherical particles have a positive effect on internal bonding (*IB*) but have a detrimental impact on MOR and MOE, which are more profiting from longer particles or fibres (Bajwa *et al*, 2015; (Klímek *et al*, 2016). Indeed, the presence of vegetal pith is reported to have negative effects on both MOE and MOR (Balducci *et al*, 2008; Klímek *et al*, 2016). On the other hand, when vegetal pith is grounded together with the fibrous tissues of the plants, a mixture of spherical and elongated particles is obtained (Nozahic *et a*, 2012). Such mixtures are unable to compactly pack in the boards, which dramatically reduces density and IB (Bajwa *et al*, 2015). Such drawback could be compensated by reducing particle size, increasing the target density of the particle boards, lowering the board's thickness (Klímek *et al*, 2016) or effectively removing vegetal pith before board formation.

Salvado *et al.* (2003) produced experimental binderless fibreboards based on miscanthus (*Miscanthus sinensis*). After harvesting, the miscanthus stems were cleaned

and chipped. The chips were steam exploded with a thermomechanical aqueous vapour process in a batch reactor to obtain a pulp. The resulting material was dried, slightly milled and used to produce the fibreboards. The pretreatment and the pressing conditions that optimise the physico-mechanical responses were determined. The boards obtained showed rather good results: a modulus of elasticity as high as 7630 MPa, MOR as high as 61 MPa, internal bond as high as 4.1 MPa, thickness swelling as low as 2.5% and water absorption as low as 8.9%. The average density of the boards was 1240 kg/m^3. Below 1100 kg/m^3, the boards did not succeed to fulfil the requirements for MOR established in EN 31094.

Bajwa *et al.* (2015) evaluated the feasibility of cattails for manufacturing particle boards for commercial applications. Straw- and cattail-based particle boards bonded with 3% of polymethylene diphenyl diisocyanate (*pMDI*) were manufactured using a hot-plate press (190°C and 1.54 Mpa for 420 s). The target density was maintained at 480 kg/m^3, and the proportion of cattail and wheat straw was varied between 100%, 50% and 25% to obtain four different formulations. Cattails (both stems and leaves) and straw were used in the form of chips of between 2 and 6 cm in size.

It was found that the incorporation of cattails resulted in an improvement of the overall properties with respect to the control of 100% straw. However, the specimens of 100% cattail did not yield the best results either. The best results were obtained for mixtures of 70% cattails and 25% straw, which exhibited superior average flexural stiffness (MOE of 446.3 N/mm^2), flexural strength (MOR of 17.95 N/mm^2) and internal bond, and lower water absorption and thickness swelling. Besides, the dispersion of measured results was lower than for the rest of the formulations. Weak bonding between straw particles due to the presence of cuticular waxy layer was assumed to be the cause of the poor results obtained for the straw-based particle boards, whilst the poor results

obtained for the 100% cattail samples were attributed to lose packing density of the randomly organised particles. According to the authors, the use of mixtures of cattail and straw aggregates for the manufacture of particle boards is feasible, and better results should be expected if the moisture content and particle sizes of the two aggregates are matched.

Binici *et al.* (2016) developed corn-cob-based composites and analysed the effect of particle size and matrix/aggregate ratio on the thermal, mechanical and acoustic insulation properties of the boards. Corn cobs were hammermilled and sieved to particles sizes between 1.6 and 6.3 mm and blended with an epoxy resin, added in 50% and 75% proportions and pressed for 1 min at room temperature and variable pressures (between 0.07 and 0.27 MPa). The resulting materials had densities ranging between 250 and 410 kg/m^3 and thermal conductivities between 0.159 and 0.075 W/mK. Pressure was found to be the main driving factor affecting the analysed properties: higher manufacturing pressure resulted in not only higher density and thus better mechanical properties but also higher thermal and sound conductivities.

Klímek *et al.* (2016) used two vegetal-pith-rich plants, sunflower (*Helianthus annuus*) and topinambour (*Helianthus tuberosus*), and a third nonwood plant, cup plant (*Silphium perfoliatum*), as raw materials for the production of particle boards. MDI and UF resins were used as bonding agents. The vegetal materials were hammermilled and sieved to obtain aggregates of 5 and 1.24 mm in size. The aspect ratio (ratio of length/width) of the aggregates was analysed. Whilst topinambour and cup plant formed rather elongated particles, sunflower particles were 'cubicle', probably due to a lower amount of fibrous tissues and/or lower lignification of fibre bundles. The size dispersion in the aggregates was found to be higher than in wood chips.

The aggregates were mixed with the resins in a drum blender using a spraying nozzle. MDI was added at 4% and 6% and UF at 8% and 12%. Mats were manually prepressed before being hot-pressed at 200°C and 3.2 MPa for 100 s to a design density of 600 kg/m^3, which is a conventional density in furniture applications. Amongst the three raw materials used, little differences were found, even though cup-plant-based boards yield slightly better results. In contrast, the type and quantity of binder played a more decisive role. The most favourable results were obtained with MDI of 6%. Although the resulting boards fulfilled the mechanical requirements for EN 312 P1 class (use in dry conditions), their performance (measured in terms of MOR, MOE, IB, thickness swelling and water absorption) was inferior to that of conventional wood particle boards.

Bektas *et al.* (2004) developed three-layer particle boards from sunflower stalks (*Helianthus annuus*) and poplar wood (*Populus alba*). The ratio of particles from wood or sunflower was 100%, 75%, 50% and 25%. The mixtures of aggregates, sieved at 1.5 mm for the middle layer and 0.8 mm for the surface layer, were bonded with UF (9% for the middle layer and 11% for the surface layer) and a catalyst (1% of ammonium chloride) and hot-pressed (24–26 MPa and 150°C during 7 min) to form particle boards of an end density of 700 kg/m^3. The moisture-related properties (thickness swelling and water absorption), mechanical properties (internal bond, modulus of elasticity and MOR) and screw-holding capacity of the panels were analysed. All the resulting particle boards fulfilled the requirements established in EN 312, for general- purpose use.

However, the performance of all the boards incorporating sunflower stalks was lower than that of the 100% poplar wood specimens. The composite made with sunflower stalks only showed the worst performance. Balducci *et al.* (2018) selected different

vegetal-pith-rich parts of crop plants, such as sunflower, topinambur, miscanthus and corn stalks and hemp shives, aiming at the production of lightweight particle boards. One-layer and three-layer particle boards, bonded with 6% pMDI and UF resins, were characterized in terms of mechanical- and moisture-related properties. Particle boards made from wood served as reference.

The vegetal materials were cut and hammer milled to produce aggregates. The pith and the bark parts were used together. The typical size of the particles was not mentioned; however, the authors report important differences in shape and density of the resulting particles. The aggregates were blended with the resin and pressed to a target density of 400 or 600 kg/m^3. It was found that density was the main drawing factor affecting the investigated properties. Lightweight boards failed to meet the requirements of P2 applications (EN 312, board for interior use—including furniture—under dry conditions), unlike most of the boards ranging 600 kg/m^3, which did comply with such requirements. For similar densities and formulations, pMDI-bonded boards yield better results. No important differences were found between one-layer and three-layer particle boards in terms of their mechanical properties. Under the same conditions, boards had higher IB than the rest of the materials, whilst corn stalks showed the lowest IB.

2.9.2 Types of Particle Boards

2.9.2.1 Single-layer Particle Board

Particleboard with a single layer is made out of wood particles of the same size that have been crushed together. It is a dense, flat board that can be veneered or plastic laminated but cannot be painted. This sort of particleboard is water-resistant but not waterproof. Particleboards with a single layer are ideal for interior use. Kinjal Mistry (2016)

2.9.2.2 Three-layer Particle Board

A layer of large wood particles sandwiched between two layers of small, dense wood particles makes up a three-layer particle board. The outer layer contains more resin than the inner layer. Three-layer particleboard has a flat surface that is suitable for painting. Kinjal Mistry (2016)

2.9.2.3 Graded-Density Particle Board

A layer of coarse wood chips is included in the graded-density particleboard. Two layers of fine wood particles are placed between this layer and the next. Particleboard of this type can be used to make wooden furniture and cabinets.

2.9.2.4 Melamine Particle Board

A sheet of melamine-impregnated decor paper is glued to the top surface of the plain particleboard using heat and pressure in this form of particleboard. To bond the particleboard and make it water-resistant, melamine-urea formaldehyde resin is used with wax emulsion. Melamine particle boards are scratch-resistant and long-lasting. They're used in a variety of applications, including wall cladding, wall paneling, modular kitchens, wardrobes, and office furniture. They come in a variety of colours and textures to provide a decorative touch to home decor. Kinjal Mistry (2016)

2.9.2.5 Cement-bonded Particle Board

This board uses cement as a bonding agent and is moisture, fire, and rot-resistant. Cement (60%), wood waste particulates such as wood chips, sawdust, and wooden shavings (20%), and water are used in the production of cement-bonded particleboard (20%). These boards are more durable, fireproof, and termite resistant due to the cement content. In the presence of moisture, cement-bonded particleboard exhibits significant expansion and shrinkage. Fire-resistant furniture, false ceilings, internal

and external walls, and permanent shuttering for concrete floors and walls are all examples of their applications. Kinjal Mistry (2016)

2.9.2.6 Laminated Particle Board

Particleboard with a laminate sheet on the surface is referred to as laminated particleboard. Particleboard gains improved aesthetics and durability with the addition of the laminate sheet.

2.9.2.7 Veneered Particle Board

A thin slice of wood known as the veneer is attached to the surface of the veneered particleboard. Veneered particleboard seems like real wood. In addition, as compared to normal particle board, veneered particleboard is more resistant to warping.

2.9.3 Particle Board Properties

Kinjal Mistry (2016) outline different types of artificial wood available in the market like plywood, block board, MDF, particle board, hardboard etc. All manufacturers sell their products and recommend their use for all purpose universally irrespective of their different properties and methods of manufacturing. Particle board is a relatively new engineered wood product made from wood waste such as wood chips, sawdust and wood shavings. Its use in home and office furniture is increasing rapidly due to its easy availability and low costs. Before buying particle board, a homeowner must be aware of particle board properties like weight, density, durability, strength, etc.

2.9.3.1 Weight and Density

As it is composed of wood chips, wood shavings and sawdust which are waste materials and have very less weight, particle boards are also light in weight as compared to medium density fiberboard or plywood. Due to its lightweight nature, they are easy to transport and handle. Although they are light in weight, their density is more than

natural wood and plywood. Medium density fiberboards and high density fiberboards are denser than particle boards. Kinjal Mistry (2016)

2.9.3.2 Strength

Particle boards have low strength as they are made from weak materials like wood chips and sawdust. They cannot withstand heavy loads and are used when load application is less.

2.9.3.3 Resistance to Moisture

One of the most concerned properties of particle board is that it has low resistance to moisture. In the presence of moisture, the boards experience swelling and development of cracks may occur. Also, on exposure to moisture, particle board gets discolored.

2.9.3.4 Resistance to Warping

Particle boards have low resistance to warping, but coating it with primer or painting the particle board, can improve its resistance. The coating also helps in increasing its strength up to some extent.

2.9.3.5 Durability

As it has low strength, particle boards are less durable as compared to plywood or solid wood. They last 3-5 years, but with proper care they have a durability of few more years. The durability can be increased by covering the surface with laminates or wood veneer. Laminated particle board and veneered particle board have useful life of 10-15 years.

2.9.3.6 Insulation

Particle boards have good sound insulation properties; thus they are used in partition walls and ceilings of recording studios and concert halls.

2.9.3.7 Fire Resistance

Particle board can be made fire resistant by attaching a layer of melamine on the top surface. Melamine particle boards are mostly used in manufacturing of industrial furniture.

2.9.3.8 Eco-Friendly

Particle boards are eco-friendly materials as they are manufactured from recycled materials and waste such as wood chips, wood shavings, sawdust, etc. Thus, it helps in environmental conservation to some extent.

2.9.4 Physical and Mechanical Properties

The current work reports on the fabrication of composite matrix from saw dust (SD) and recycled polyethylene terephthalate (PET) at different weight ratio by flat-pressed method. Wood plastic composites (WPCs) were made with a thickness of 15 mm after mixing the saw dust and PET followed by a three phase press cycle. Physical properties (Density, Water Absorption (WA) and Thickness Swelling (TS)) and Mechanical properties (Modulus of Elasticity (MOE) and Modulus of Rupture (MOR)) were determined base on the mixing ratios according to the standard. WA and TS were measured after 2 h and 24 h of immersion in water.

The results showed that as the density increased, the SD content decreased from 90 % to 50 % into the matrix. However, WA and TS decreases when the PET content increased in the matrix. Remarkably, the MOE and MOR attained a maximum point at 964.199 N/mm2 and 9.03 N/mm2 respectively in 50 % SD content. In comparism with standard, boards D and E can be classified as medium density boards while A, B and C are low density boards. The results indicated that the fabrication of WPCs from sawdust

and PET would technically be feasible for indoor uses in building due to favourable physical properties exhibited. The mechanical properties response showed that it cannot be used for structural or load bearing application.

Reused and waste thermoplastics are a portion of the real segments of worldwide municipal solid waste (MSW) and they display a promising crude material hotspot for wood-plastic composites (WPC) development, particularly in view of the extensive volume and ease of these materials. Primarily, polyethylene terephthalate (PET), polystyrene (PS), polyvinyl chloride (PVC), and highdensity polyethylene (HDPE) are essential constituents of plastics in MSW.

The mix of the blended waste plastics can be changed relying upon the provincial propensities and periods of a year and on the method of waste gathering. Reutilizing the post-devoured polymeric materials lessens the natural effect and the utilization of virgin plastics. Most single polymer plastics produced using oil are moderately simple to reuse. In this manner, with a productive accumulation, detachment and reusing framework, disposal of plastics can be reused into new items with just the expansion of vitality.

The administration of plastics waste is one of the significant issues confronting current society as it is non-degradable and poisonous when consumed. Polyethylene terephthalate (PET) is one of the exceptionally asked for plastic on the planet and among the most well-known plastics waste. PET has low water ingestion, high hardness and quality and PET utilized as a part of different applications like sustenance compartment, bottle, plastic strands, toys, wrapping materials, movies, and tars, in spite of the majority of the advantages, however, PET stay in nature. Waste plastics can also be considered as potential material in the development of WPCs relying upon their softening temperature. In order to enhance the compatibility of constituents' materials,

a binder is thus necessary to improve the quality of product formed. In this way, expanding interest has of late been centered on the reusing of plastic waste, particularly PET for these different purposes which could keep the natural contamination.

Wood has been reported in the development of composites panel with specific attention to hardwoods, softwoods and the mixtures of various species. However, due to ranger service controls, wood deficiency, and practical utilization of timberland assets have asked specialists everywhere throughout the world to find elective approaches to utilize various types of lignocellulosic biomass for composite board creation. Urea-Formaldehyde (UF) has been the real adhesive for wood-based particleboards.

In spite of the fact that Formaldehyde containing tar is broadly utilized today as a glue in the fabrication of particleboard, researchers are looking for elective cement frameworks because of the exceptionally lethal nature of formaldehyde. Particle board have being produced from agricultural waste such as sugarcane, wheat straw, tree leaves, sunflower stalks, maize cobs, maize husks, coconut, banana bunch, palm kernel shell, saline Jose tall wheatgrass and rice husks. Currently, an increase in the demand of wood composite panels as necessitated the choice for an alternative material which is economically viable, with less processing technique. This demand has made the potential use of sawdust a viable particulate material an option in the manufacture of WPCs.

Manufactured from Wood, Bamboo and Rice Husk the physical-mechanical properties of particleboards manufactured with wood (Eucalyptus grandis), bamboo (Bambusa vulgaris) and/or rice husk (Oryza sativa) particles, combined or not, were assessed. They were produced in the following proportions: 100% wood; 100% bamboo; 100% rice; 50% wood and 50% bamboo; 50% wood and 50% rice husk. In order to characterize the manufactured particleboards, their physical (density; moisture content;

water absorption and thickness swelling) and mechanical properties (static bending; internal bonding and screw withdrawal) were assessed. The results indicated that the use of rice husk caused reduction in particleboard quality. Particleboards manufactured with bamboo showed better quality than those using rice husk as raw material. For most parameters, the particleboards manufactured exclusively with wood particles showed similar performance to bamboo and wood-bamboo particleboards.

Owing to the rise in wood consumption, the reserves of native woody species have been decreasing, causing the search for new renewable lignocellulosic materials that may efficiently meet the demand. This environmental pressure supports research regarding new products and a better utilization of the raw material available. Residue reutilization has been increasing, thus several researches have been investigating the characteristics of particleboards produced with these residues. Furthermore, there is the possibility of combining wood with other lignocellulosic materials aiming at obtaining more profitable products and with environmental marketing strategies, without reducing its quality.

The particleboard industry in Brazil uses mostly wood shavings from reforested, resulting in a higher quality product due to better control of the homogeneity of raw material. However, in view of Brazil's agricultural boom and the resulting increase in agricultural wastes, a recent alternative for particleboard production may be the use of agro industrial lignocellulosic wastes to replace solid wood particles in the manufacture of composite panels. At first, any lignocellulosic material can be used as raw material for particleboard manufacturing. Besides wood, they can use residues from agribusiness such as: cereal straw, bagasse of sugar cane, cornstalks and corn cobs, cotton stalks, kenaf, rice husks, sunflower stalks and hulls, among others.

Within these, rice husk presents the highest potential for utilization. Rice is one of the most consumed cereals in the world. Only in Brazil, which is just the ninth largest producer in the world, a production of nearly 12 million tons of rice per crop (about 2% of the global production) is estimated, whereas most part is concentrated in its southern states. Considering that the husk accounts for nearly 20% of the grain weight, annually, it would be generated about 2.4 million tons of this residue by that country Ndazi et al. mentioned that rice husk is one of the agricultural residues easily available in large amounts and, therefore, can be considered an excellent raw material for manufacturing particleboards.

However, particleboards produced with this material have been presenting deficient gluing owing to the lack of direct interaction between this product and commercial adhesives. This behaviour was also verified by Ajiwe et al. and Melo et al, while assessing particleboards manufactured with different proportions of wood and rice husk particles. Apart from residues, the raw materials found in large amount at regional level can decrease the final cost of the product. This is the case of bamboo, which has been used at industrial scale in several Asian countries such as: China, India, Thailand, Vietnam and Malaysia. In Brazil, in spite of genera and species (232, whereas 174 are endemic) diversity, bamboo's potential has been poorly utilized. Several studies have indicated that particleboards using bamboo as raw material present satisfactory performance with respect to physical-mechanical properties. Hiziroglu et al, while studying particleboards manufactured with different proportions of wood (Eucalyptus camaldulensis), rice straw and bamboo particles, observed. Again straw-bamboo, and for the combination between them, inferior mechanical properties (internal bonding, modulus of elasticity and modulus of rupture) compared to those manufactured only with wood particles. These authors still verified, with respect to physical properties,

lower dimensional stability for these particleboards. However, wood-bamboo particleboards obtained similar or better performance than those manufactured only with wood particles. In the present study, it was assessed the physical and mechanical properties of particleboards manufactured with wood, rice husk and bamboo particles, in different combinations.

Particle boards were prepared from sawdust and urea-formaldehyde resin (UFR) on compression moulding machine. The particleboards were produced at a compression temperature of 150°C; a pressure of 10tons was applied for 15 minutes. The amount of sawdust was kept constant at 20g while UFR was varied from 30ml, 35ml, 40ml and 45ml respectively. The control sample (CS) was the 50ml UFR without any saw dust. The properties of the particleboards were tested using ASTM methods. The results showed that the properties of the particleboards are a function of the percentage composition of the binder (resin) and the filler (sawdust).

The results showed that as the URF content increased from 30ml to 45ml, the mechanical properties increased. The hardness increased from 88.6 shore A to 99 shore A while the percentage of water absorption decreased as the UFR content increased. The swelling thickness decreased as UFR content increased. The density increased as URF content increased. Urea Formaldehyde, Particle Board Composite, Sawdust, Mechanical Properties.

Particleboard has been defined as generic term for a panel manufactured from linger cellulosic materials, usually wood, primarily in the form of discrete pieces or particles, as distinguished from fibers, combined with a synthetic resin or other suitable binder and bonded together under heat and pressure in a hot press by a process in which the entire inter particle bond is created by the added binder, and to which other materials have been added during manufacture to improve certain properties. Historically, the

products from the light wood technology were very expensive and exclusive. They were used in the aeronautic field or in the automotive field. Over the time, the light wood products could be produced cheap, but with a better quality through increased efficiency in production processes, research, and development.

This trend is very strong in the furniture industry. Particleboard is cheaper, denser and more uniform than conventional wood and plywood and is substituted for them when appearance and strength are less important than cost. However, particleboard can be made more attractive by painting or the use of wood veneers that are glued onto surfaces that will be visible. There are over a hundred particle board plants in operation today worldwide and particle board is one of the strongest reconstituted panel products and is considered as an ideal substitute to wood and plywood.

2.9.4.1 Modulus of Rupture

The modulus of rupture (MOR) is an important property determining the applicability of particleboard for structural components. Many processing parameters and their effects on the MOR have been studied; the most widely reported parameters are bored density and particle configuration and orientation.

2.9.4.2 Density

The density of the board divided by the density of the wood equal the compaction ratio (Hse 2013). Hse illustrated a high correlation between compaction ratio and MOR for particleboards at three different densities produced from nine hardwood species from low to high specific gravity. Unfortunately, the equation presented to fit the plot of MOR versus compaction ratio does not fit the data (Hse 2013). The board density used in the calculation is the average board density; therefore, com paring the relationship of MOR to compaction ratio between researchers is useless unless similar vertical density

gradients are present in the respective boards. Howard (1974) determined the densification (compaction) ratio for flake boards made from slash pine stems and root material. The MOR for boards made from the root material was higher than the same-density board from stem wood and, since the density of the root material was less than the stem wood, the compaction ratio was higher for the root material. Vital et al. (2015) found that particle boards from four exotic hardwoods of widely varying specific gravity, made to constant board density, had higher MOR values as the compaction ratio increased from 1.2 to 1.6. However, boards made to the same compaction ratio from different furnish specific gravities did not result in constant MOR values, as reported by Hse (2013), but increased linearly with increasing board density. Stewart and Lehmann (2015) found the MOR to increase linearly with increasing panel density for four hardwood species ranging in specific gravity from 0.37 to 0.67 (OD weight, volume at 8 percent moisture content) . However, the modulus of rupture decreased as the species density increased i.e.as the compaction ratio decreased for all board densities. As the furnish density increases, the MOR values decrease at constant particleboards densities, although a sharper drop in the MOR at low board densities and high wood densities would be expected than shown by this curve . Obviously, compaction ratio is directly proportional to the particleboard density for furnish with constant specific gravity. All studies in which board density versus MOR has been determined report an increase in modulus of rupture with increasing board density that is, as the compaction ratio increases the modulus of rupture increases. Consequently, compaction ratio may be an excellent method of quantitatively determining the relationship between board density and modulus of rupture.

2.9.4.3 Modulus of Elasticity

The modulus of elasticity (MOE) is an important property because it is a measure of the stiffness, or resistance to bending, when a material is stressed. The effective MOE of particleboard is measured by mid-span loading as described in ASTM D 1037 (2006). The non-uniformity of platen- pressed particle board in the thickness direction prevents the determination of a true MOE. Effective MOE used here is board stiffness divided by moment of inertia in general, modulus of elasticity and modulus of rupture are affected similarly by various processing parameters. Increasing board density increases both properties; increasing surface density and surface particle alinement increases both properties; and higher adhesive contents normally increase MOR and MOE. Vital et al. (2015) have calculated regression equations for MOE versus MOR values for the data of their respective studies. The effective MOE is not determined as frequently as MOR by various researchers; consequently, there are many reports in the literature in which no information is available on MOE. As was done in the section, “Modulus of Rupture, " the parameters affecting MOE will be reviewed individually in the following density and particle configuration and orientation subsections.

2.9.4.4 Density

Particleboards of constant average density possess higher MOE values as the wood density decreases as the compaction ratio increases. Hse (2013) plotted MOE versus compaction ratio for phenol formaldehyde-bonded particleboards from flakes of eight different hardwoods with widely different wood densities while Vital et al. (2015) indicate that for a given MOE, a compaction ratio of either 1.2 or 1.6 is possible, depending upon the board density. Consequently, unless the vertical density gradient is determined and its effect recognized, erroneous conclusions can be drawn about the effect of other variables, such as particle configuration and resin con tent, on the

effective MOE. Most researchers attempt to circumvent the vertical density gradient effect by using a constant press closing rate, press temperature, and mat moisture content.

There was also a significant resin content- density inter action indicating more efficient resin usage at the higher densities. Lehmann (2015) found a linear relationship between MOE and density at all resin contents studied. Heebink et al. (2015) measured the vertical density gradient and MOE for particleboard pressed with 5 and 15 percent moisture con tent in the core and surfaces, respectively. The high density regions within 1/16 inch of the surfaces resulted in high effective MOE values.

2.9.4 .5 Particle Board Configuration and Orientation

The modulus of elasticity is strongly dependent upon flake length; longer flakes produce particleboards with substantially higher effective MOE (Heebink and Hann 2015; Lehmann 2015). The effect of particle thickness on MOE does not appear to be as well defined as the effect of length. Stewart and Lehmann (2015) did not find a significant effect of flake thick ness on the effective MOE for particleboards produced from cross-grain flakes in the thick ness range 0.006 to 0.018 inch. Gatchell et al. (2017) found an increase in MOE when flake thickness decreased from 0.030 to 0.015 to 0.007 inch.

2.9.4.6 Water Absorption and Thickness Swelling

Rofii and Widyorini (2017) stated that thickness swelling and water absorption were physical properties that related to particleboard's response to soaking conditions. The highest and lowest water absorption values were on control and waterproof treatments. We presumed the waterproof properties of waterproof resisted water to penetrate to particleboard. Waterproof also had negative response to water absorption value.

Waterproof coating decreased water absorption almost three times compared to untreated. Water absorption (WA) of the particleboards against the soaking time. There were two-step processes for the water uptake patterns. During the first two hours, more than half of the final absorbed water occurred. This was followed by a period of very slow and consistent water uptake. The higher initial water absorption rate can be explained by the diffusion phenomenon, like a fluid migration, where the water spreads itself through the capillaries, vessels and cellular walls of the sago particles. Two forms of water up-take patterns were present: interstitial water and bound water. The interstitial water is contained in the cellular cavities and bound water is retained in the cellular walls. The rate of water absorption depends on the difference between the saturation water content and the water content at a given time, which is called the driving force. The moisture diffusion into the particles takes place because of moisture gradient between the surface and the centre. As absorption proceeds, the water content increases, diminishing the driving force and consequently the absorption rate. Generally, the interstitial water molecules are relatively weaker than the bound water molecules, thus, water will migrate from the more concentrated medium towards the less concentrated one. The size and shape of the individual particle furnish are significant factors that influence the water absorption process. The water absorption rate increases with the chip particle thickness because in thinner particles, the maximum over pressure in the centre of a material is higher and the distance for transporting the water from the surface is halved compared with the bigger size and the main pressure release occurs in the longitudinal direction. When the longitudinal and latitudinal dimension is doubled, the maximum over pressure increases by a factor of more than two because of the larger length of longitudinal and latitudinal flow necessary for water absorption to be stable. The total time is longer in order to achieve the equal volumes,

a smaller particles will achieve faster than the bigger one due to the highest resistance to flow in the thickness direction. The ability of composites to absorb water is an indicator of their porosity.1mm particle had the least porosity when applied in composite. As a result, it had the least water absorption compared to the smallest and biggest particles. During the particleboard fabrication, small size of particles that had bigger spaces between each other caused the water molecules to easily substitute the spaces in between. On the other hand, 2mm particles having the same problem just slightly different then 0.6mm. 1mm particles were the suitable size for the particleboard fabrication and the spaces between the particles made it difficult for the water molecules to penetrate into the particleboard. 1mm particles showed good inter-particle bonding between the particles and matrix during the hot-press process and had reduced the porosity of the boards which made the boards to become water repellent. Thickness swearing of particleboards affected by the weight fractions. The results indicated that a decrease in the weight fraction of fiber (increase in UF content) affect the thickness swelling. This is because sago was less repellent to water as more resins were incorporated into the board. The thickness swelling could be affected by the bonding quality between the particles and the adhesive properties. An increase in adhesive creates better bonding quality as compared with small amount of UF. The presence of sago bark in the particleboards resulted in higher water resistance. This is because the presence of polyphenolic extractives in the barks reacted with the UF and improved the water resistance properties. The high values obtained from the TS tests were due to the high percentage of highly absorbent particles in the panels. The particles were very short and constituted a high percentage of total fiber content, thus, creating a very large and highly absorbent surface area. The highly porous structure of the board allowed the water molecules to penetrate into the board and increased the water uptake, resulting in

high water absorption and caused the board to swell and subsequently led to an increase in the thickness swearing.

Water absorption and thickness swelling normally are determined on the same specimen in both the ASTM and VPS methods. The ATSM method specifies horizontal submersion of a 12- X 12- inch specimen and notes vertical submersion will result in absorption of more water; therefore, comparisons between water absorption and thickness swelling results obtained by the two techniques is not possible. The specimen size used in the ASTM test by various researchers is variable, limiting direct comparisons. Johnson (2007) studied 24 - hour water soaking in both vertical and horizontal positions of 26 commercial particleboard specimens, 3 X 15 inches. In general, more water was absorbed by the vertically soaked specimens, although five of the 26 particleboards absorbed more water in the horizontal position. The vertically soaked samples absorbed the moisture more quickly than did the horizontally soaked samples, but at an equal moisture content increase there was very little difference in the thickness swelling. However, because the vertically soaked specimen absorbed more water and absorbed it faster, it also had more thickness swelling at any given soaking time. Johnson (2007) also measured the moisture content and thickness swelling of boards conditioned at 65 percent relative humidity and 70° F for 44 days. These samples were initially conditioned for one month at 30 percent relative humidity at 90° F. The thick ness swelling at 65 percent relative humidity was less than 2 percent and the moisture con tent increase was approximately 2.5 percent. The data indicate that samples attained a constant EMC and thickness swelling during the 154 days at this humidity. However, the data for the 90 percent humidity condition definitely showed thickness swelling still increasing rapidly at the end of the 44-day period. Thickness swelling versus moisture content was approximately linear between 2 and 14 days at

this condition. After 14 days the moisture content increased less than one percent for the remaining 30 days at this relative humidity but the thickness swelling increased more than 3 percent and was still increasing when the test was terminated. This indicates that a relaxation or other time dependent phenomenon such as spring back, independent of moisture content, is control ling the thickness swelling.

2.9.4.7 Effect of Board Density on Thickness Swearing of Particle Board

The effect of board density on the thickness swelling of particleboard is confounded with the spring back behavior. Higher density boards will possess more compressive set than lower density boards when both are made with the same wood furnish. Therefore, it is not surprising that thickness swelling is normally reported to increase with increasing board density (for example, Gatchell et al. 2007

Vital et al. (2015), with particleboards from exotic hardwoods of four different wood densities, studied the water absorption and thickness swelling properties. Two compaction ratios were used and boards were made with all possible species mixtures of one, two, three, and four species. Water absorption and thickness swelling values were determined for all boards over the relative humidity increments of 30 to 90 percent, 50 to 90 percent, and 30 percent to water soaking for 24 hours. Unfortunately, the specimen sizes used are not reported, nor is the conditioning time at each relative humidity given in the paper. Since the highest density board was 0.93 gm/cm3 (grams per cubic centimeter) (OD weight, volume at 65 percent relative humidity) the time to equilibrium moisture content can be assumed to have been quite long. Not surprisingly, the water absorption in the 24- hour water soak test was highly correlated with the board density (Vital et al. 2015). For all species combinations, the higher compaction ratio (1.6) always absorbed a lower amount of water than the lower compaction ratio (1.2). Water entry into the higher density boards occurred at a slower rate due to the decreased

porosity and the increased wood material. Total water absorbed from the atmosphere (30 to 90 and 50 to 90 percent relative humidity increments) was also higher in the lower compaction boards in all cases , but the difference between the two ratios was much less significant (approximately 1 percent moisture content) . The longer times at these relative humidity obviously allowed the moisture to equalize much more uniformly through the board than was possible in the 24- hour water soak. With only a few exceptions, an increase in board density resulted in a decrease in thick ness swelling for all three exposure conditions. The lower moisture absorbed by the higher density boards was one possible explanation for this behavior. Additional reasons given were the increased inter particle bonding at the higher density or the higher moisture content during pressing, as reduced porosity of the high - density mat limits the escape of moisture and allows increased compressive set in the final panel. The rate of thickness swelling was initially less than the rate of water volume absorption which, according to Suchsland (2005), indicates internal swelling. As the moisture content increased, the rate of swelling was higher than the rate of water volume absorption and was attributed to internal failures in the lower density core. Suchsland (2005) stated that efforts to reduce thickness swelling should concentrate on reducing the horizontal density distribution so that high- and low -density regions are eliminated. This ideal can never by obtained with wood particles but it can be approached as the particle size decreases. Lehmann (2015) found a relatively minor effect of density on thickness swelling with 1 and 30 - day water soaking. This is to be expected because the slower diffusion rate in the higher density material prevents attainment of moisture equilibrium in the 24- hour soak.

2.9.4.8 Particle Configuration

The effect of particle size and shape on the thickness swelling of particleboard has been widely reported in the literature. Turner (2014) was one of the first investigators to systematically study this variable. His test method consisted of determining the thickness after two water soaking –oven drying cycles and expressing this thickness as a percent of the original thickness. This procedure is more severe than the presently used 24 -hour water soak. Turner (2014) showed that flake length has no significant effect upon thickness swelling. Long, thin, narrow strands with 2 percent phenolic resin resulted in a poorer thickness stability than the flat flakes, but, with increased resin contents of 4 and 8 percent, the stability of the board produced with the strands was better than the flakes at equal resin content (resin solids on OD wood). Lehmann (2015), in his study of Douglas fir flakes 0.5, 1.0, and 2.0 inches long and 0.030 and 0.045 inch thick, found no significant effect of flake length on particleboard thick ness swelling with either the VPS or relative humidity exposure tests. However, the thinner flakes resulted in slightly less thickness swelling, especially in the OD-VPS test. Kimoto et al. (2011) reported a slight decrease in thickness swelling, determined by the water soak test, as the particle dimensions increased for low density particleboard. No effect of particle configuration on thickness stability was evident in the relative humidity exposure test. Heebink and Hann (2015) found northern red oak flakes 1 inch long produced a more stable particleboard than did flakes 0.25 inch long. With flakes thicker than that, stability was improved with increasing flake length. Beech (2010) studied the thickness swelling properties of phenol-formaldehyde bonded particleboard made with angle - cut particles of Scots pine. The angle -cut flakes were produced in such a manner that the orientation of the grain was approximately 20 ° out of the flake plane. This allowed a portion of the large dimensional movement across the grain to be

shifted to the linear dimensional movement in the produced particleboard and further allowed the wood longitudinal direction to be slightly oriented in the board thickness. This reduced the thickness swelling for particleboards produced for these angle -cut particles below the level obtained in particle board produced with standard particles. However, as would be expected, this particle also resulted in boards with substantially reduced strength. Beech (2010) did not determine linear expansion but this, too, would be expected to increase with the angle - cut particles. The use of angle -cut particles as a method for reducing the thickness swelling in particle board appears to have limited potential. The available literature appears to be practically unanimous in that better thickness stability is obtained with boards produced from thin particles than from thick particles. The lower wood mass in each particle and the increased number of particle - particle inter faces possibly allows better dispersion of the hygroscopic swelling into the inter particle voids. Consequently, this swelling into the macroscopic board voids, not internal swelling within the wood particles, results in less thick ness swelling. Much less agreement is found regarding the influence of particle length on thickness swelling. In general, it appears that increasing particle length improves the thickness stability. A possible reason for this may be as the particle length increases and the particle is bonded to a larger region of the board , it is more effective in dispersing localized swelling stresses over a larger region i.e., it serves as a moderating influence and reduces the effect of high density regions on thickness swelling .

2.10 General uses of Particle Board in the Construction Industry

2.10.1 Uses of Particle Board in Flooring

Jaydutt Tailor (2017) stated that Particle board is used as a flooring material in temporary structures where there is less application of loads. Also it is widely used as covering for hardwood floors, as hardwood boards have low resistance to scratches to protect them. Wood veneer particle board or laminated particle board is used in flooring where finished aesthetic look is desired.

2.10.2 Uses of Particle Board in Flooring Underlayment

Particle board is extensively used as flooring underlayment or as a base for parquet flooring, wood flooring, or for carpets. For this purpose, the particle boards are treated with special chemicals and resins to make them waterproof or termite proof. Mahadev Desai (2019)

2.10.3 Uses of Particle Board in Partitioning or Wall Paneling

Particle boards are used in wall partitions, as they are non-load bearing members in the structure. For cost-effective options, particle boards can be used as they have thermal and sound insulation properties. Laminated particle boards are extensively used in wall panels as they give finished walls. You can select from a variety of design in laminated particle boards for wall panels. Jaydutt Tailor (2017)

2.10.4 Uses of Particle Board in False Ceilings

Laminated particle boards and cement particle boards are widely used in false ceilings. Due to their thermal insulation properties they are extensively used in false ceilings for centrally air-conditioned rooms. Particle boards are extensively used as ceiling tiles for auditoriums, computer centers, cinema halls and theaters

and in as display boards in commercial establishments. In building construction it is used in false ceiling and paneling due to its thermo-acoustic insulation properties.

2.10.5 Uses of Particle Board in Core Material for Doors

Particle boards are also used as a core material in solid core doors as well as in flush doors. Particle core is the most commonly used in manufacturing doors, as it provides flat and smooth surface for bonding with the door skin. It also has good screw-holding capacity for fixing hinges, unlike medium density fibre board.

2.10.6 Uses of Particle Board in Furniture

There are numerous uses of particle board in furniture industry. Particle boards are extensively used in residential as well as office furniture. Wood veneer particle board are gaining popularity as they are durable and perform better in moist environment as compared to plain particle board. So they are used in kitchen areas and bathrooms in the form of modular kitchen cabinets, storage units, countertops, table tops, wardrobes and dressing units. Plain particle boards are useful in interior areas like bedrooms which have beds, wardrobes, storage units, etc. It is also used in making shoe racks, computer tables, book shelves, television cabinets, etc.

Nowadays office furniture is mass-produced by using particle boards. Readymade units of office furniture are directly supplied to the offices with decorative laminated particle board tops. Kinjal Mistry (2017)

2.10.7 Uses of Particle Board in Commercial Industry

On commercial scale, particle boards are used in television, speaker boxes, sewing machine tops, display boards, automobiles' parts and in other products which

requires furnished surfaces. Wood veneer particle boards are very extensively used in this industry.

2.11 Advantages of Particle Boards

2.11.1 Cost-effective

Laminated particle boards and veneered particle boards provide aesthetic effects at lower prices than plywood.

2.11.2 Lightweight

Due to this property, they can be **handled and transported easily**.

2.11.3 Easy to maintain

They do not dent or distort easily. Moreover, they require minimum maintenance and can be cleaned easily

2.11.4 Easy to work on

Particle boards have better screw holding capacity than MDF, so they are widely used to make furniture that can be assembled using screws.

2.11.5 Good insulator

They have thermo-acoustic insulation properties, so are suitably used in speakers and false ceilings in theatre, auditoriums.

2.11.6 Eco-friendly

They use wood waste such as wood chips, sawdust, wooden shavings, and bagasse (residue of sugarcane after the juice is extracted).

2.12 Disadvantages of Particle Boards

2.12.1 Low strength

They can be **easily damaged** during transportation due to their low density. They cannot support heavy loads.

2.12.2 Easily damaged

They expand and warp**.** Discoloration may occur under extreme conditions.

2.12.3 Not durable

They have shorter lifespan compared to MDF and plywood due to their lower strength and damage by moisture.

2.12.4 Toxic

They are manufactured using urea formaldehyde resin which is the source of formaldehyde gas**.** The resin may break down and release the toxic gas even after many years of installation, which is carcinogenic for humans i.e. causing cancer.

2.13 Adhesive used for particle board manufacturing

Adhesives commonly used for the manufacture of particle board include urea-, phenol-, melamine-formaldehyde condensation products, PVA, isocyanates and adhesives with a tannin and sulphite waste liquor base.

2.13.1 Urea-formaldehyde

Urea-formaldehyde is chemically known as the urea-methanol .It is a non-transparent thermo setting resin or plastic and is made from urea and formaldehyde heated in the presence of a mild base such as ammonia or pyridine. The resins are very useful in adhesives, and also in the MDF, and the molded objects. It is first time synthesized in 1884 by Hölzer, with coworker Bernhard Tollens. In 1919, Hanns John (1891–1942) of Prague, Czechoslovakia obtained the first patent for urea-formaldehyde resin.

The properties of UF resins were listed by Pizzi (1994) as follows:

1. The hardness of the resin.

2. The low flammability of the resin.

3. The good thermal properties of the resin.

4. The absence of colour in the cured polymer.

5. The adaptability of the resin to a variety of curing conditions. A. Pizzi (1994) Urea formaldehyde adhesives as we know about 1 million metric tons of urea-formaldehyde are produced every year and is used worldwide as the data provided and Over 70% of this production is then put into use by the forest industry products and also used as a great resin for bonding particleboard (61%), medium density fiberboard (27%), hardwood plywood (5%), and laminating adhesive (7%).

Urea formaldehyde is the very common chemical and is mostly used because of its chemical properties. Examples are textiles, paper, foundry sand molds, wrinkle resistant fabrics, cotton blends, rayon, corduroy, etc. also used to glue wood together. Urea formaldehyde is mostly used when producing electrical appliances casing also desk lamps.

It is widely chosen as an adhesive because of its property of high reactivity, wonderfully performance and low price. It is a chemical combination of urea and formaldehyde and is not poisonous in nature. The Examples of amino resins include tires from automobile industry in order to improve the bonding of rubber to tire cord, paper for improving tear strength, molding electrical devices, molding jar caps, etc.

Instead, the adhesive market is of great importance for UF resins, with particular importance in the production of the particle board, plywood, and in the furniture industry. To prepare a suitable resin, formalin is first neutralized. The mixture is boiled under reflux, typically for about 15 min, to give dimethylol urea and other low molar

mass products. The resins is then acidified to pH 4, with formic acid, and reacted for a further 5–20 min. The resulting resin is then stabilized by neutralizing to a pH 7.5, to give a water-soluble resin with about 50% solids content, normally reduced to a 70% solids by vacuum distillation. The resulting product is QC tested for viscosity, solids content, pH value (must be between 7.3 and 7.5), and its reactivity with a standard hardener. Resins are commonly available with urea to formaldehyde molar ratios ranging from 1:1.05 to 1:2.2. Higher formaldehyde ratios give greater clarity, the best water resistance, marginally superior mechanical properties, longer shelf-life (up to two years), and greatest reactivity.

The degree of condensation is quite important to achieve only limited absorbance into wood (for adhesive keying) and good thin film coverage as a continuous layer of adhesive over a substrate's surface (i.e., to maximize other forms of adhesive bonding). Rye or wood flour applied to the wood substrate reduces the extent of resin penetration, improves adhesive spreading properties, and limits the amount of adhesive applied. The resins are hardened by acidic conditions. Ammonium chloride or phosphoric acid, an acid donor, is employed. This reacts with formaldehyde to give hydrochloric acid. H examine is also formed during this reaction:

$$4NH_4Cl + 6CH_2O \rightarrow N_4(CH_2)_6 + 6H_2O + 4HCl$$

About 1.5 parts ammonium chloride per 100 parts of the resin solution are generally used, the hardener being added as an aqueous solution.

At one time, UF was used extensively in the manufacture of plywood, but today it is less important. For this purpose, a resin (typically urea-formaldehyde molar ratio of 1:1.8) -hardener mixture is coated onto a wood veneer. This is plied together with other treated veneers and pressed at 95–110 °C under pressure at 1.4–5.5 MPa. UF-bonded plywood is suitable for indoor application, but is generally unsuitable for external use.

So-called *marine plywoods* are more suitable for exterior use, where PF, resorcinol–formaldehyde, or melamine-modified resins are employed.

UF resins continue to be used in large quantities in general wood assembly work in the furniture industry. In most cases, a resin-hardener mixture is applied to the surfaces to be joined and then clamped under pressure while hardening occurs. It is also possible to coat the resin onto one surface and the hardener onto the other surface, allowing them to come into contact in situ and thus avoiding the short pot-life of the mixture. Gap-filling resins may be produced by incorporating plasticizers (e.g., furfuryl alcohol), and fillers to reduce shrinkage, cracking, and crazing.

One of the largest applications of UF resins nowadays is in the manufacture of chipboard. Wood chips are mixed with about 10% of resin-hardener solution and the mixture is pressed in a multi-daylight press for about 8 min at 150 °C. Resins with low free formaldehyde content are used to minimize odor, both during processing and from the finished product in service. A rather high urea to formaldehyde ratio subjected to only a low degree of condensation is necessary in order to achieve a low, free formaldehyde content.

Wood chipboard is free from grain and is thus essentially anisotropic, with mechanical properties being approximately the same as the average of the properties of the original wood measured along and across the grain. The water resistance of chipboard is poor but, being isotropic, it does not warp as long as it is able to swell freely in all directions.

Urea–formaldehyde adhesives are widely used in the wood industry for joining wood to make useful forms such as interior-grade plywood and particle board. The primary reaction is the addition of formaldehyde to urea to generate methylolated amines under basic conditions which can then further condense with other areas to create a three-dimensional network under acidic conditions. These reactions can take place at room

temperature or at elevated temperatures depending upon the molar ratio of formaldehyde to amine and if any catalyst is present. Catalysts include ammonium chloride or ammonium sulfate, which is buffered by the addition of tricalcium phosphate.

Urea–formaldehyde adhesives came under scrutiny in the 1990s due to suspected emission of formaldehyde when the bonded wood was exposed to high-humidity conditions. It was found that the emission of formaldehyde could be reduced substantially if the molar ratio was reduced from the standard 1.55 to −1.85 (formaldehyde to urea) to levels as low as 1.02 to −1.1. This change could be accomplished by careful addition of urea to the cooking process. Another way in which the emission of formaldehyde could be lowered was by the addition of melamine to the resin cook.

Urea-formaldehyde is a non-transparent thermosetting resin, made from urea and formaldehyde heated in the presence of a mild base such as ammonia or pyridine.

It is characterized by high tensile strength, flexural modulus, and heat distortion temperature, low water absorption, mould shrinkage, high surface hardness, elongation at break, and volume resistance. It is used in many manufacturing Processes. Examples include decorative laminates, textiles, paper, foundry sand moulds, wrinkle-resistant fabrics, cotton blends, rayon, corduroy, etc. It is also used to glue wood together. Urea formaldehyde was commonly used when producing electrical appliances casing (e.g. desk lamps).

Urea-formaldehyde (UF) resin is extensively used as a binder adhesive for the production of wood-based panels such as medium density fiberboard, particleboard and hardwood plywood for interior uses. UF resin is an excellent adhesive with features such as virtually colourless glue lines, low price, mold and fungi resistance, and ease

of handling (e.g.; mixing, applying and cleaning). UF resin can be successfully bonded with most species of wood in many combinations. However, formaldehyde emission is the main disadvantage property of the UF resin. The lower formaldehyde/urea (F/U) molar ratio, the lower the content of free formaldehyde in the UF resins. The formaldehyde emission of UF resin has been declining as a result of new resins and resin technologies.

The use of Urea-formaldehyde for the production of particle board and as an adhesive resin has been widely reported due to its high reactivity, good performance, and low price. The use of Urea-Formaldehyde for the production of particle board using saw dust has also been reported. Studies on the use of buckwheat stalk in particleboards bonded with urea-formaldehyde resin adhesive have been reported. It has reported that one of the major difficulties in the processing of wood-based particle boards with urea-formaldehyde is that urea-formaldehyde is a volatile gas with strong odor. Production of particleboards, as stated earlier, involves the use of a binder (resin). A large amount of binder is being used in particleboard industry for the production of high-quality products.

The binder accounts for up to 32% of manufacturing cost in the glue-wood composite industry. Various types of binders have been used in the manufacture of particleboards and they are classified as satisfying interior or exterior use requirements primarily on the basis of their response to moisture and/or temperature. At present, the principal ones are formaldehyde condensation polymers, such as Urea-formaldehyde (UF), Phenol-formaldehyde (PF), Phenol-resorcinol formaldehyde (PRF), Melamine formaldehyde (MF) and their derivatives (i.e. modified formaldehyde condensation polymers). Others include; isocyanate adhesive, gypsum, nitrogenous modified amylaceous binder, magnesia, etc. The relatively low cost and proven performance of phenol-formaldehyde

and urea formaldehyde resins have made them the most important adhesive systems for composite wood products.

These two resins are formed by step-growth (condensation) polymerization reaction of formaldehyde (CH2O) with phenol (C6H5OH) and urea (H2NCONH2) respectively Urea is a colorless and odorless crystalline compound, CO(NH2)2, with a melting point of 132.7°C, also known as carbamide. It is found abundantly in the urine of humans and other mammals. In lesser quantities, it is present in the blood, liver, lymph, and serous fluids and is found in the excrement of fish and many other lower animals. Urea is produced mostly in the liver as the end product of protein metabolism. The nitrogen in urea, which constitutes most of the nitrogen in the urine, is produced mainly from food protein, but part comes from the breakdown of body cells.

Urea is also present in various fungus molds as well as in the leaves and seeds of numerous legumes and cereals. The compound is soluble in both water and alcohol and is slightly soluble in ether. Urea is prepared synthetically by the Wohler synthesis, which was devised in 1828 by the German Chemist Friedrich Wohler. $CO2 + 2NH3 \rightarrow NH3CONH3 + H2O \leftrightarrow H2NCOONH4$. Due to its high nitrogen content, commercially prepared urea is used in the manufacture of agricultural fertilizers. Urea is also employed as a stabilizer in nitrocellulose explosives and is a basic constituent of synthetically prepared resins. Urea-formaldehyde (UF) resins are composed of molecules that cross-link into clear, hard plastics. Properties of UF resins are similar to the properties of phenolic resins.

As the names imply, these resins are formed by condensation reactions between urea (H2NCONH2) and formaldehyde (CH2O). Two main steps are recognized in the reaction of formaldehyde with amino compounds to form useful resins.

Addition of melamine to the resin causes an improvement in the hydrolytic resistance of the cured resin.

2.13.2 Polyvinyl Acetate (PVA)

PVA is a type of thermoplastic that belongs to the polyvinyl ester family. It is manufactured by the polymerization of vinyl alcohol and was discovered way back in 1912 by Fritz Klatte. Nowadays, PVA glue is more commonly called wood glue, white glue, or school glue. Although PVA glue has become a catch-all term, there are a few types of PVA glue with subtle but significant differences. Standard PVA glue is useful for the binding of paper and cardboard. PVA wood glue is specifically designed to absorb into the surface of wood, enhancing its adhesive properties. There is also a water-resistant version of PVA glue that can withstand moisture and mildew but will still dissolve if submerged in water according to Tout, Bomba et al. (2014) wood adhesives.

There is also some confusion between the "white glue" that is often used in schoolwork and bookbinding and the so-called "carpenter's glue" which has a slightly yellow tinge. These are both PVA glue and can be used interchangeably for paper, wood, or any materials that are compatible with PVA glue.

Conner, Bhuiyan (2017) Module in materials science and materials engineering outline the Properties of PVA Glue as follows:

2.13.2.1 Adhesives Suitable for porous materials

One of the distinguishing characteristics of PVA is that it is readily absorbed by porous materials. This means that, as PVA glue dries, it creates an even stronger bond between materials that it has absorbed into. Common materials that take advantage of this

property are wood, cardboard, paper and cloth. Conner, Bhuiyan (2017) Module in materials science and materials engineering

2.13.2.2 Adhesive is water-soluble

If PVA glue needs to be applied in thin and even coats, it can be easily diluted with some water to improve its wetting properties. Being water-soluble also has its downside; however, in that dried PVA glue easily re-dissolve when submerged in water. Conner, Bhuiyan (2017) Module in materials science and materials engineering

2.13.2.3 Adhesive is non-acidic

Conner, Bhuiyan (2017) opined that PVA does not alter the pH of the material it comes in contact with. This makes PVA a safe option for binding of all types of paper products. Those who have worked with paper a lot know that it can deteriorate very quickly if it comes in contact with any acidic medium.

2.13.2.3 Adhesive remains clear and flexible when dry

PVA glue is very suitable for arts and crafts as it dries completely clear and does not detract from its visual appeal. This transparency is retained even after a long time, unlike other glues which tend to turn yellow. It also retains flexibility even when dry, which is crucial for bookbinding and woodworking. Conner, Bhuiyan (2017)

2.13.2.4 Adhesive is non-toxic (if not ingested)

PVA glue has pretty much been the go-to adhesive for schoolwork. It's a fairly non-toxic glue as its components do not leach through the skin. However, it's still not safe to be ingested. Conner, Bhuiyan (2017) Module in materials science and materials engineering

2.13.2.5 Adhesive is Odourless

Unlike other polymer-based glues, PVA does not emit any irritating or solvent-like odor. This is also one of the reasons why PVA glue is considered safe for use for children stated by Conner, Bhuiyan (2017)

2.14 Phenolic Resins in Plywood

Plywood belongs to a class of materials referred to as composite wood materials or wood resin boards. The other wood products included in this category are particle board, fiber board, wafer board, and strand board. Phenolic resins serve as the bonding material in these products.

Formulations for the adhesives used for composite wood materials. These composite products other than plywood (particle board, fiber board, wafer board, and strand board) are considered part of the adhesive and bonding market and are treated as such under Fibrous and Granulated Wood. Together, these fibrous and granulated wood products account for 15.5% of the phenolic resins market (compared to 49% for plywood.

The use of phenolic resins in plywood was introduced into the U.S. in 1932 with the importation of the Goldschmidt glue line ("Tego film") from Germany. Tego film is a thin sheet of paper impregnated with phenolic resin. Typically, the thin sheets of paper are placed between layers of veneer (wood), and the layers of veneer are hot pressed at temperatures of 100°-150°C and pressures of 700 to 6000 psi. The use of phenolic resins (in Tego film) in plywood was a response to the demand for exterior weather-proof plywood. Prior to the introduction of Tego film, the bonding materials for plywood were casein glue, peanut meal, and soybean meal, which are strictly for interior use.

The adhesive material for exterior grade plywood is resole-type phenolic resin with a swell-resistant filler such as coconut shell. Other fillers used are oat hulls, wheat flour,

and chalk. Wheat flour and chalk are mainly used as extenders for adhesiveness. The extenders are also used to reduce cost and porosity. Sodium hydroxide serves as a solubilizer in phenolic resin in water. Phenolic resins compete very favorable with urea-formaldehyde bonded plywood, and most of the plywood made today is phenolic resins based. The lack of homogeneity in wood composition is a problem in the production of plywood.

The degree of penetration or saturation of the wood by the resin determines the level of bonding. It is customary for plywood manufacturers to carry out tests and experimentation to determine the right resin formulation for each wood or veneer system. Phenolic resins-based plywood find application in the making of interiors and parts for automobiles, boats, ships, trucks trains, machines, and tool handles. Some of the luxury cars, such as Mercedes and Cadillacs, use plywood for dashboard decoration. Particle board, fiberboard and oxychloride are artificial wood made by damaging, dipping and grinding wood shavings, wood wool and timbering residue into wood pulp, mixing the pulp with glue, and then heat-pressing and drying the pulp. And the glues used in the procedure are plant or animal glue (soy-adhesive, blood glue), synthesis resin adhesive (phenolic resin, urea-formaldehyde resin), and inorganic gelling material (concrete, magnesite, etc.). These kinds of wood are of low apparent density and strength. And they are mainly used as heat proof and acoustical material, and after facing treatment they can also be as ceiling board or partition board.

. Particleboard by its reconstituted nature has very uniform properties across the board in all dimensions. The resin system used has a major impact on the properties of the board with higher resin loads of moisture stable resins being used for the higher-grade panels. The strength of the boards is generally lower than plywood, having a MOR

value of 16–22 MPa compared with the 35–45 MPa of plywood (Stark *et al.*, 2010; Cai and Ross, 2010).

Chipboard also has a tendency for low water resistance though this can be modified by using moisture-resistant resins (Wood Panels Industry Federation, 2014b) and additives (giving the panel a greenish colour in cross section).

2.15 Classification of Particleboard According to EN 312 (Cen, 2010)

Particle board is classified in Europe, based on use, by the EN 312 (CEN, 2010) standard (summarised in Table 2.3).

Table 2.3. Classification of particleboard according to EN 312 (CEN, 2010)

Classification	Use
P1	General board for use in dry areas
P2	Non-structural board (including furniture) for use in dry areas
P3	Non-structural board for use in dry or humid areas
P4	Load-bearing boards for use in dry areas
P5	Load-bearing board for use in dry or humid areas
P6	Heavy-duty load-bearing board for use in dry areas
P7	Heavy-duty board for use in dry or humid areas
P8	Extra heavy-duty board for use in dry areas

Particle board is usually coated or laminated to improve its aesthetic value and is easily treated with fire retardants (for which the cross section is usually reddish in colour) or with preservative chemicals.

2.16 The Strength of Particle Board (Bonded Sawdust)

The strength of particle board primarily depends on the chemical content of the parent wood and binding agent during production process. Chemical modification could improve the dimensional stability of the material Papadopoulos and Gkaraveli (2003).

Thus, the strength of particleboard unlike conventional wood can be purposefully enhanced by the manufacturer. It may all depend on the chemical composition of the content. Rowell (2011) revealed that the natural reactivity of lignocelluloses can be utilized to enhance their properties with the resulting material being superior in terms of performance and versatility. This implies that the nature of wood shavings could also be used to enhance the strength properties of particleboard.

Rowell again states that "The basic types of chemical modification use simple mono-functional modifying agents while others use dysfunctional or even poly functional modifying agents". Thus, the strength of particleboard may depend on the manufacturer as well as the purpose for which he intends to use it. Rowell specifies that one of the most practical of these is the reaction of a hydroxyl group with acetic anhydride, known as acetylation. To buttress the points asserted earlier, (Papadopoulos & Traboulay, 2012) report that recently, acetylation has been successfully employed to improve the dimensional stability of particleboard.

2.17 State of the Forest

Forests are essential for health of the environment. They help to control the climate, recycle water and oxygen, prevent soil erosion and provide homes for the most of the world's species of plants and animals. Despite all these benefits, human activities are rendering the forest incapacitated to offer such service to the planet. That notwithstanding, decades of forest recovery policies aimed at salvaging the situation, the rich forests continue to be depleted at an alarming rate (Okra, 2012).

According to Park (2011), the developing world lost two million square kilometers of their forest between 1980 and 1995 and most of the loss was in tropical rain forest. According to the Food and Agriculture Organization (FAO) (2011) report, factors like

unsustainable agricultural practices, bush burning, excessive logging and other activities contribute to Ghana's high rate of deforestation.

In agreement to FAO (2011) report, Okra (2013) also put on record that it is estimated that about 60% of the Ghanaian forest is lost to agriculture. While Dei (2010) stated that, "Forest plants are also invaluable for their medicinal and pharmacological uses". Dei (2010) again agreed that the contribution of other activities aside agriculture to deforestation may go unnoticed. For instance, in 2004, the Timber Industry Development Division (TIDD) estimated that there are more than 40,000 carpenters in the country. This implies that aside woodcarvers and farmers, there are some 40,000 other people who are directly involved in the use of wood.

Other studies have shown that wood species felled for carving purposes are many even though they have no official data Dei (2010). The Centre for International Forestry Research (CIFOR) info-brief (2012) reported that during timber harvesting, up to 80% of the wood mass is left behind in the form of the crown, stump and branches. Even though these raw materials could potentially be used for the production of small carved items, they are left to waste. Frimpong Manso (2010) as cited in Okra (2000) recorded that less than 11,000 kilometer square of Ghana's total land area is covered by forest, meaning a huge part of the original forest cover has been lost to deforestation.

Marfo (2010) recorded that the current land area of Ghana is about 23.85 million hectares (ha). The Ghanaian forest is divided into two vegetation zones, each with different forest types. The high forest zone (HFZ) forms 34% whiles the savannah zone forms 66% of the total land area as cited in Domson (2017). Hawthorne (2015) explained that Ghana's high forest zone occupies about 82,000 km3. This high forest zone is sub divided into nine different vegetative segments with distinct variety of plant species corresponding to soil conditions and rainfall. Ghana's deforestation rate is

estimated to be approximately 65,000 ha per year. On record, Ghana has about 216 forest reserves that are managed for protection and timber production. As at 1995 afforestation had fallen short and the country could only boast

Of 15,000 hectares of plantation by the country's Forestry Department which was done in the 1960's (Appiah, 2016). Since the colonial era, the exploitation of timber for commercial purposes has been part of Ghana's economy. It is only during the start of the Economic Reforms Programme (ERP) 1 in 1983 that deforestation became a serious issue of concern because of the over-exploitation of the forest resources. Okra (2012). From 1990-2005 Ghana had lost about 20% of its forest cover and the annual deforestation rate as at 2006 stood at 2.0% (Domson, 2017). Domson further reported that an estimated 2 million people in Ghana depend on forest for subsistence use. There is therefore the need to develop the artificial silvicultural industry to supplement forestry resources in order to address the imbalance between supply and demand of the resource (Appiah, 2016). The most sought after tree species like Sese, Ebony, Danta, Kusia which are used as raw materials for carving are said to be rare and locally extinct because they are depleted in the Ghana forest (Asiama, 2018).

2.18 The Nature of Ghanaian Wood Carving

Carving is the analytic study of the medium using the requisite tools to remove the unwanted parts to arrive at a final product which has been previously conceived in the storehouse of the mind (Boateng, 2014). As stated by Ross (2014) almost all meanings attached to indigenous art forms in Ghana is on philosophical foundations. Though Ghanaian carvers produce items that are meant for domestic, religious, social and economic usage, Hudson (2011) brought to the fore the origin of Ghanaian art that are linked to the religion of the people. Some wares are at times produced to serve both political and educational purposes. The products of Ghanaian wood carvers include

mortars, ladles and spoons, door panels, ancestral masks and figures, stools thrones, drums and some musical instruments, weaving bobbins and other ritual and ceremonial objects (Adu-Agyem, 2010).

Per this definition, carving does not pertain to the use of only one material. Different materials could be engaged in carving provided they have the properties that make them workable, as Boateng (2014) stated that "Many media could be used to produce artifacts ranging from wood, ivory, metal, bone, marble, plaster of Paris, stone, PVC and many other forms of hardware". However, the most available material in a particular community influences the carving medium that dominates their carving practice. Wood carving as an aspect of carving is of ancient origin in Ghana. Amoh (2019) described Wood carving as "an age-old tradition in Ghana, practiced by various ethnic communities in Volta, Western, Eastern and Ashanti regions". Owing to the versatility of wood carving with respect to the diverse media used, even though wood carving is practiced in every part of Ghana, it is predominantly practiced in the southern part of the country.

To attest to this fact, Boateng (2014) states that "wood carving begun prominently in the forest areas". Wood carving is seen as an expression of traditional philosophies through art. Owusu (2013) authenticated this in his observation that "the inspiration behind the traditional woodcarving in the olden days was religious". Although times have changed, this art form still holds on to its canon rudiments of practice. Boateng (2014) recorded that the wood carving industry of the Akans is an indigenous craft tradition that is still vibrant despite the world's rapid change.

The researcher (Gordon Owusu Yeboah) attests to the fact that Ghanaian wood carving has widened up and improved tremendously. Introduction of modern machinery and tools have enhanced production and the rudiments of design. Boateng (2014) further

states that carving in Ghana begun as a communal form of expression based on the ideas and ideals of the entire community or ethnic group. It can be said that carving in Ghana as stated by Boateng (2014) then was confined to societal functionality in relation to a particular group of people. Even though carving with much emphasis on aesthetics and individual expression was not originally accepted.

Boateng (2014) further indicated that carving in Ghana as a result of the rapid changing world, has now married together both foreign tourists‟ tastes and indigenous philosophies. Thus, bringing into being, works that are now meant to satisfy both local and international standards regardless of their personal or aesthetic emphasis expressed in the work. The trade in handicraft has grown into a big prosperous business which is effectively and closely tied with the tourism trade in helping boost the economy of the country. Okra (2012) attested to the fact that "Woodcarving represents the permanence and continuity of the nation since it is the embodiment of Ghanaian culture".

Tourists in recent times prefer traditional wood carving to any other art work or craft. Tourists may be so much attached to wood carving pieces because of their traditional meanings. Even though wood carving has transformed through the ages, they are still identified with the culture of the people. This may be primarily because of the abundance of raw materials in these areas. Boateng (2014) reported further that wood as a material is one of the most important materials the Akans of Ghana use in the art of expressing their thoughts, through carving.

2.18 History of Wood Carving in Ashanti Region

The Asantes are noted for their expertise in a variety of specialized visual arts. These include weaving, wood carving, ceramics, and metallurgy. Of these arts, wood carving is divided into many branches, each with its own specialists. Among the major products

are wooden sculptures of outstanding artistic quality and the talking-drums ("Ntumpan"). The famous wooden "stools" are symbolic and ritual objects rather than items of furniture (Adu-Agyem, 1990). "In Ashanti, a generation or so ago, every stool in use had its own special name which denoted the sex, or social status, or clan of the owner" (Rattray, 1927). Development in wood carving gained impetus due to demands of religious beliefs. This quality gingered many carvers to become experts (Nana Frimpong Boadu, chief carver of Otumfuor, personal communication, 2012). Many of Ahwiaa wood carvers became master carvers of Asantehene (King of Ashanti Kingdom) who is regarded as the intermediary between the gods and the people (Edusei, 2004). The kind of carved objects produced were highly a matter of meeting royal demands of the Asantehene. He has been the power house and commander-in-chief whose demands propelled the growth of Ahwiaa wood carving industry. Ahwiaa, well known for traditional wood carving centre, is a small town located on the main Kumasi-Mampong highway, about 14 kilometres north of Kumasi in the Kwabre District of Ashanti region of Ghana. It has a population of about 5000 people. The major products are mainly traditional stools, statuettes, "Akuaba" (fertility) dolls, animals and domestic products such as mortars, drums, mashing bowls, door panels, wall hangings, masks, to name a few. The main occupation is peasant farming while some of the population are wood carvers. Wood carving, according to tradition, has been the preserve of males. Women do not carve because it is considered indecent for a woman to spread her legs and place a block of wood between them for carving. This is indecent exposure. Also, women, in respect of their monthly menstrual condition, were not included in the carving trade (Nana Kwadwo Koduah, personal communication, 2012). However, modernity has changed the tradition such that women now are free to take up wood carving provided they are physically capable and are interested in the trade. In

addition to this freedom, women today form an integral part of the wood carving trade. Wood carving has been the sole business of middle aged males with apprentices. The average age of a wood carver at Ahwiaa is 50 years. The oldest wood carver at the time of this research was 75 years, whiles the youngest was 25 years. Previously, young people served as apprentices to master carvers. But with acceleration of education in Ghana, many young persons are now in school, leaving the apprenticeship in wood carving in the hands of a few non-school goers and Junior High School graduates (field survey, 2012). A few blacksmiths serve as providers of simple metal tools for carving. Other tools are purchased from shops in Kumasi. The basic tools used in Ahwiaa are chisels, knife, "adze", axe, gouges just to mention a few. The basic materials are wood, sand paper, wax, lacquer, shea butter and soot mix, wood dye, etc The logs of wood which were formally cut from the forest by the carvers are now sold to the carvers by timber contractors. The products are sold locally; tourists have also intruded the market and a few carvers are exporting their carved works to other International Journal of Business and Management Review Vol.1 No.3, pp.166-187, September 2013 Published by European Centre for Research Training and Development UK(www.ea-journals.org) 168 countries. The value of carving at Ahwiaa includes teaching morals, maintaining standards of behavior and attitudes, upholding traditions, providing functional, symbolic and purely aesthetic objects. Wood carving is a household work in the Ahwiaa village which has been passed on from generation to generation. The concept of wood carving is communal that is an artwork is owned by many. However, modernity has caused the emergence of new ways of doing things which are worth studying.

2.19 The Role of Carving in the Promotion of Tourism in Ashanti Region

Promotion of tourism products According to Rowley (1998) promotion is used to communicate with customers with respect to product offerings. Promotion is used by organisations to communicate with customers with respect to their product offerings. Kotler and Armstrong (2004) see promotional strategies to include all means through which a company communicates the benefits and values of its products and persuades targeted customers to make buys. Lazer (1971) stressing from the typical marketing point of view maintains that promotion is the company s strategy to cater for the marketing communication process that requires interaction between two or more people or groups, encompassing senders, messages, media and receivers. Dibb et al. (1994) agree with Lazer and also contend that promotion is concerned with ensuring that customers are aware of the products that the organization makes available to those customers. In a similar development, promotion has been defined as the art of stimulating interest in what a business has to offer customers in the market place (Hingston, 2001). Source (accessed 2008 November) From the above definitions; it can be submitted that to have good quality tourism potentials and sculpture products sold at attractive prices is not enough but to generate sales and profits, the added benefits of these products and services have to be communicated to customers. Also, using promotional efforts by marketers of products is about bringing their products to the attention of their target markets, and reminding or persuading customers to purchase those products (Ofori, 2008). These are the main explanations being offered by the above mentioned authors in their definitions of promotion. In the present study, promotion involves operators of tourism potentials in the Ashanti Region communicating the added merits of the various tourism products and services for the

purpose of attracting prospectors who may be either foreign or local or both. In some forms of promotion and service delivery, communication in both directions can be achieved simultaneously, and since two-way communication is the only real form of communication, promotion which is associated with two-way communication is to be encouraged. Examples of such two-way promotion emerge largely from the contexts of services marketing and relationships marketing in which tourism potentials in Ashanti Region are no exception. In services marketing, for example, promotion can be part of the service delivery. Exchanges between the service agent and the customer can elicit information about customer requirements, and also permit the service agent to explain the organization s products and how these might meet the customer s needs. Similar kinds of exchanges can occur in the relationship marketing interest in business-to-business marketing transactions where the sales person is a significant agent in the establishment of relationships between customer and the organization. A more formularized approach, the use of loyalty and reward cards, in say supermarkets, offers another approach which embeds both promotional and market research activities. Mercer (1996) in emphasizing that communication must be a two-way process says that the ideal form of promotion is the conversation which takes places between the expert sales professional and his or her customer. It is interactive and conversational and specific to the needs of both. Other forms of promotion, which deal in the average needs of groups of people; can only hope to approximate to this ideal. Nevertheless, as Mercer acknowledges, much promotion, especially in consumer markets, can appear to be predominantly a one-way process in which the producer decides on a marketing message and selects channels through which to communicate that message. In such context there is a feedback on the effectiveness of the promotional strategy, but since this is largely in the form of sales, it can be difficult to differentiate between the role of

promotion and of other factors in the marketing mix in respect to the significance of their contribution to market success. The information of marketplace is an interesting mixture of consumer and business-to business marketing. For example, libraries are often concerned to promote services to end-users or consumers, and increasingly online search services and other Web search services are seeking to capture the end-user market. At the same time, library suppliers, online search services, database producers and publishers of journals and abstracting and indexing services have often viewed their primary market to be other organizations such as libraries, businesses and public sector organizations.

The History of Sculpture Sculpture is a three-dimensional art work created by shaping or combining a hard and or plastic material, sound, and or text and or light, commonly stone (either rock or marble), metal, glass, or wood. Some sculptures are created directly by finding or carving; others are assembled, built together and fired, welded, moulded, or cast. Sculptures are often painted (accessed 2009 July 13). Carvers in Ashanti also use raw materials like stone, metal, glass, wood, etc for their sculpture works. All this raw materials are used in producing the pieces because they are readily available to the sculptor and less expensive in procuring and less cumbersome in terms of preparation. Sculptures are created to reflect the culture of the Region in which they are made. From the materials and techniques used to create the piece to the function of the sculpture are very different from Region to Region. In West Africa sculptural figures have elongated bodies, angular shapes, and facial features are ideal rather than an individualistic. These figures are used in religious rituals and the surface is often coated with materials placed on them in ceremonial offerings. In contrast to these sculptures are the ones of Mende-speaking peoples of West Africa. Their sculptures are made of wood and have broad, flat surfaces while the arms and legs are shaped like

cylinders. In Central Africa the key characteristics include heart shaped faces that curve inward and patterns of circles and dots, although some groups prefer more of a geometric and angular face and form. The materials used range from mostly wood all the way to ivory, bone, stone, clay, and metal. Overall though, the Central Africa region has very striking styles that is very easy to identify and the area in which the sculpture was produced in. Eastern Africa is not known for their sculptures but one type that is done in this area is pole sculptures. These are a pole carved in a human shape and decorated with geometric forms, while the tops are carved with figures of animals, people, and various objects. These poles are then placed next to graves and are associated with death. Africa s oldest known clay figures date from 400 to 600 A.D. and have cylindrical heads. These clay figures have a mixture of human and animal features. Other than clay figures there are also wooden headrests that were buried with their owners. The headrests had styles ranging from geometric shapes to animal figures. (Accessed 2009 July, 27) In tracing the history of sculpture in Ashanti Region, reference has to be made to the sculpture pieces produced by sculptors in the West African Sub-Region that are similar to that of sculptors found in the Region that can be compared in terms of similarities to the ones mentioned in the literature. They possess features like elongated bodies, angular shapes and facial features that represent an ideal rather than an individual. Ashanti s attach superior belief to their sculpture pieces since they serve wide range of purposes. Some of these purposes are for charms and amulets, personified gods, masks, etc. The sculpture pieces of the Ashanti have been accepted by all and sundry in all manner of ceremonies such as sporting activities (in the form of athletics, football etc.), entertainment (beauty pageant, and other reality shows). During these ceremonies, trophies and plaques are carved to give to contestants who emerge victorious.

In Africa, south of the Sahara, wood is the natural material for carving. In the 21st century, sculpture in wood is still very much a living tradition. This is evidenced in the sculpture works of carvers found in the various sculpture centres such as Ahwiaa, Ohwimase (Trabuom) etc. The sculpture products produced by these carvers are used for various purposes including interior and exterior decorations. They also portray Ghanaian culture, traditions, and beliefs. Tribal carving is done for a clear and practical purpose. A figure may represent an ancestor, destined to stand in a shrine. A mask may be intended for use by a shaman just once a year in a special dance. A post may be designed to prop up a chief's veranda or to form part of a palisade round his house. An elaborate chair is likely to be for the chief himself to sit on. All of them will be better if carved in a dramatic or propitious way. The human face and form is used in a myriad of different ways to provide masks, free-standing wooden figures, or decoration for gable ends, door posts and ceremonial seats. In Ghana and for that matter Akans; people found in the Ashanti Region are noted for engaging in tribal carving as an aspect of sculpture. Their works have the purpose of functioning like ones mentioned in the above literature. Whatever the reason for the range of tribal art, the result is an unrivalled display of the power of the imagination. The basic subject, as in Western sculpture, used to be visualization but the tribal sculptor is liberated from the strait jacket of realism. His ingredients may be limited to the parts of the body, but he constantly reassembles them in new dimensions and relationships. From a central axis of the eyes, nose, mouth, navel and genital organs, to the peripheral cast list of hair, ears, arms, breasts, legs and buttocks, there is no predicting which of these elements will take the starring roles in any one production. Startling imbalance is restored to balance by the force of strong design. It is hard to know whether a particular image may be intended to seem sad or terrifying (or neither, or even nothing), for this is a subjective

matter on which an outsider may often be mistaken. But in these carvings there is no mistaking the energy and playfulness with which the human body is turned, by confident distortion, into such a gallery of wonderful creatures. Promotional strategies in tourism potentials Husain (2007) has catalogued a number of promotional strategies that can be adopted to have tourists sites attracted to tourists around the globe. It is important to note that the promotional strategies catalogued by Husain can be applicable in the Ghanaian context. In order to make tourism as an all season as well as purposeful activity in the state of Uttaranchal, it is necessary to develop as well as promote adventure tourism, sport tourism, wild life tourism, in addition to pilgrimage tourism. All these activities mentioned by Husain can be developed in the Ashanti Region in places like forest reserves such as Bobiri Forest, Bomfobiri wildlife sanctuary, Atwia rock formations, Digya national park, Mframabuom caves and lake Bosomtwi, also a water body where adventure tourism can be developed. Besides, in order to extend the tourist seasons, various adventure sports competition like river rafting should also be organized immediately. In this vain, water bodies like Lake Bosomtwi and River Offin can be developed strategically for tourism products like adventure sports and rafting can be organised in these sites for the purpose of adding to the many potentials in the Region. According to Husain (2007) whilst promoting tourism with the aim of attracting foreign tourists, efforts must be made to attract domestic tourist as well. In this case, sites such as Lake Bosomtwi, Bobiri forest reserve, Owabi wildlife sanctuary, Bomfobiri wildlife sanctuary and the host of others found in the Region need to be promoted so as to attract the needed visitor numbers. SPA tourism can be developed in some of the forest reserves in Ashanti Region as a way of adding up to the tourism potentials in the Region. Services such as recreation, entertainment, relaxation and the rest are the notable ones that can be developed to

comprise the SPA tourism potential. It has been suggested that while constructing and upgrading the accommodation facilities, the requirement of the tourist at different places for accommodation should be considered. Tourist information centres should not only be located at important tourist destinations of the Region but also at national and international gateways, so that the tourist particularly foreigners will not be misguided by untrained tour guides or other persons and will get the right information from these places. Furthermore, in order to make correct as well as speedy information, all the information centres should be connected with each other through computerization. All these information centres should be provided related literatures and brochures, booking services for package tours and so on (Brenya, 2001 and Husain, 2007). In supporting the view of Husain and Brenya, the following strategies must be adopted: accommodation facilities must be upgraded in terms of hotels, motels, and guesthouses in areas closer to the sites. Information centres in the tourists sites located in the Region must be upgraded to suit current and modern demands so as to prevent misguided information always communicated to tourists both foreign and domestic tourist. Local people should also be motivated as well and involved in the tourism process. It has been suggested that the people of the Region should come forward to help in providing safe and secure atmosphere for the tourists (Brenya, 2001 and Husain, 2007). The residents in the Region must also create an environment very conducive for the tourists to feel more at ease anytime they visit the sites. The end result of this will go a long way in promoting the people of the nation in totality. Another motivation is organizing most of the public functions such as swearing-in of heads of state, seminars, entertainment, lesser known sporting activities in which fees to be charged will be affordable to all and sundry to patronise such places. There is an urgent need for ecotourism. Planned infrastructure and tourism development without disturbing the ecological balance of

Uttaranchal is to be given top priority (Husain, 2007). In applying this concept in Ghana, it needs to be mentioned as a core fact that forest reserves and water bodies comprising eco-tourism in the Ashanti region should be preserved, and efforts made to plan for such sites. Again, in the quest of developing sites with ecological status, developers must be advised not to destroy the various ecological species but rather preserve them. It has been suggested that in order to attract more and more foreign tourists, advertisement in foreign journals, magazines and newspapers should be given in foreign languages. Besides, translation of tourist s literature in foreign language through different agencies is another positive step in this direction (Husain, 2007). Again, stakeholders like the Ministry of Tourism, Ghana Tourist Board together with their private counterparts must be up and doing to have their promotional efforts seen and read in foreign journals, magazines and newspapers. It has also been suggested that in addition to establishing a film city in the region, incentives should also be given to the players of Bollywood and Hollywood to establish their studios (Husain, 2007). The Ghanaian film makers must use the various tourist sites in their movies as settings or background. This is because the movies have a wide coverage both international and domestic which is capable of attracting the viewers to this site adopted as settings. Familiarization tours of travel writers as well as travel agents from different part of the country should be organized immediately. These groups should be invited for a free visit of the major places of Uttaranchal in order to enable them to popularize Uttaranchal as a destination of tourists. Such programmes will definitely be boosting the tourism in Uttaranchal (Husain, 2007). Ghanaian travel writers and agents from different parts of the country must organize familiarization tours for both domestic and international tourists to attract them with the aim of achieving regular patronage. It has also been suggested that different independent tourism organizations like tour

operators, hoteliers, restaurants and so on should also be involved in promoting tourism into the sites (Brenya, 2001 and Husain, 2007). These organizations should make use of various promotional tools at different times. During the off-seasons, the tourism industries should make use of personnel selling tool for persuading customers and other institutions to choose Uttaranchal as a venue for conference and seminars (Husain, 2007). To Husain, effective promotional tools such as advertising, sales promotion, personal selling, PR, internet, event marketing POP, POS can be adopted by promoters to persuade and influence prospects to choose tourist sites located in the Ashanti Region of Ghana. This is because the Region has been branded as the cultural hub of Ghana. This is factual in that culture is one of highly patronized products in global tourism. Another suggested strategy for promoting Uttaranchal is the creation of strong brand identity. Brand identity should be created just as created by Malaysia as truly Asia and so on. In addition to creating strong brand identity, it should be propagated either through advertisement or through taking part in international exhibitions, etc. This step will help them in promoting the state of Uttaranchal on the similar lines (Husain, 2007). From Husain s assertion, a strong brand identity must be created to distinguish tourism in Ashanti Region from that of other regions in Ghana and Internationally. Objectives of Promoting Tourism and Sculpture Pieces According to Dibb et al, (1994), Allen (1999) and Borvée and Thill (1992) more specifically, the objectives of any promotional strategy will be drawn from an appropriate mixture of the following roles: Informing or Building Awareness Management may need to make their audience aware that their product exists, and to explain exactly what it does. Informing includes giving information to intermediaries as well as to the consumer of the product (Dibb et. al, 1994 and Allen, 1999). To promote tourism potentials and sculpture pieces in Ashanti Region, the operators and producers of such businesses must make it a duty to bring to

the domain of the general public that such products and services do exist and they are for sale. These public may refer to the prospects that are interested in tourism potentials and may be targeted by the operators. Persuasion this is an important stage in creating favorable attitudes towards the business and its brands. Persuading, attempts to convince the customer to purchase the organization s product instead of some other products that may also satisfy the same need. Operators of tourism potentials located in the Ashanti Region are duty-bound to develop effective strategies that can be implemented to convince existing customers and prospects to intensify their patronage of the tourism services found in the Region. Stimulating demand this is where marketers use promotion to inspire customers to take action to buy their products. In the case of products that a customer has not previously purchased or has not purchased in a long time, the promotional efforts may be directed at getting the customer to try the product (Borvée and Thill, 1992) (accessed 2008 November, 11). This is often seen where owners of tourist sites allow for free trials of their services. It can be said that tourism products and services with an established customer-base, promotion can encourage customers to increase their patronage by providing a reason to purchase such products or services sooner and in greater quantities than they normally do.

Differentiating products one of the primary purposes of promotion is to differentiate a product from its competitors (Borvée and Thill, 1992). For the purpose of this study; owners of tourist sites in Ashanti Region can run advertisements with the specific purpose to differentiate their products and services from the host of others in Ghana and the world at large (Borvée and Thill, 1992). Promotion as a management tool can be utilized by the individual operators for the purpose of distinguishing their products and services from that of their competitors. In the main, promotion can be intensified with the combine efforts of all operators and producers of Tourism potentials in Ashanti

Region that attractions found in the Region are distinct and unique than the ones found in the other Regions. Countering competitors Promotion can also be used to counter the marketing efforts of competitors. This has to do with situations where owners of tourist sites in Ghana strategically sometimes come out with promotional efforts to make up for the ones coming from the domain of their competitors (Borvée and Thill, 1992). It is only promotion that can be used to counteract and offset campaigns coming from the camp of competitors from other Regions. Also, with operators found within the same Region, promotion can be used for that same purpose as mentioned earlier. Responding to negative news Sometimes the competition is not another company selling similar products (Borvée and Thill, 1992). Fisher (1986) as cited in Borvée and Thill (1992) recounts a situation where Coors spent years trying to neutralize the effects of clash with the AFL-CIO. The problem started when Coors managed to get an AFL-CIO local decertified (stripped of the authority to represent employees), and it was magnified when William Coors, the brewery s chairman was quoted as making some remarks that were interpreted as derogatory toward blacks. The battle was on, and every time Coors tried to enter a new market area, it faced a boycott organized by the union. Coors countered this with its Getting Together with America promotional campaign, trying to convince people that it was a company that really did care about the everyday working person. Negative remarks or statements found in the competitor s advertisements can only be responded to professionally; using promotion strategies that are potent to neutralize such falsities. Smoothing demand fluctuations many companies face the challenge of seasonal demand, in which customers buy more during some parts of the year and less during others (Borvée and Thill, 1992). In Ghana and specifically in the Ashanti Region, operators of these tourist sites can sell less during non-festive periods and occasions but that does not mean their products have to be idle. They must use

promotion to tell prospects the need to patronize made-in Ghana goods (in the case of sculpture pieces) or services (in the case of tourism potentials) especially the ones from the Ashanti Region. Influencing public behavior finally, promotion is used to influence public behavior (Borvée and Thill, 1992). The effort of promoting tourism potentials and sculpture products should not be the duty of only the operators and the sellers but it should be the combine efforts of stakeholders in the industry like Ghana Tourist Board, Ministry of Tourism and Diaspora Relations, Ministry of Trade, Ghana Standards Board, Association of Ghana Industries the District Assemblies and the Traditional Authorities, to mention but a few. Again, the operators of these tourist centres would appreciate if Ghanaians patronize their facilities by organizing public functions like Church services, weddings (e.g. mass weddings in the Churches or Joy FMs Bridal Fair), engagements, naming ceremonies and a host of others. According to Edward et al. (1991) and Parr, Pingy (1997) lack of promotion can result in dwindling awareness of the value of the services offered, consequent decline in use, and subsequent marginalization of the Library. 2.5 Importance of promoting tourism through Sculpture works According to Brenya (2001) the tourism industry is one of the industries that has registered the most remarkable growth in recent times. The author has catalogued the following as the benefits to the tourists and the host country and for the purpose of this study. They are as follows: Tourists spend money it has been established as a fact that tourism is now the third foreign exchange earner after gold and cocoa in Ghana. The spending from tourism contributes significantly to GDP. The visiting sites like Bobri Forest, Bomfobiri wildlife sanctuary, Atwia rock formations, Digya national park, Mframabuom caves and lake Bosumtwi, craft villages (such as Ahwiaa, Ntonso, etc.) will have the greatest of all opportunities in the form of traders

selling their tourism products and services to these tourists. Products and services can range from accommodations, transportation, catering and sculpture works.

Employment it leads to varied forms of job creations for people involved in the tourism business. For the purpose of this study, people like hotel operators, workers found in the tourist sites like narrators, drivers, bead-makers, and sculptors. Country becomes popular on the larger note Ghana as a country becomes more popular as a result of promoting tourism potentials whereas, in the minor extent Ashanti Region is attracted to myriad of tourists around the globe. Little wonder, Ashanti Region has been branded as the cultural heartbeat of Ghana due to its numerous tourism potentials. A lot of investment can go in to this form of branding so as to catch the eyes of world tourism. Economic development through tourism income This is evidenced through the spread of infrastructure development of tourist sites in the form of the tarring the roads leading to the sites, improving of communication networks, building of hotels and restaurants, offering employable training programs to artisans involved in the trade. All these go to the larger extent of these places being promoted for businesses of all forms. Culture enhancement this comes about through cultural interpretations and pride in one's culture. Typically, Ashanti culture is seen and promoted in the global platform when standardized forms of cultural narrations and interpretations are done to visiting tourists in the sites. Environmental conservation Conservation of the environment is done through protecting the water bodies, the forest reserves, wildlife, historic and other cultural sites. For the purpose of this study, the sites that can be conserved environmentally in the Ashanti Region are Bobri Forest, Bomfobiri wildlife sanctuary, Atwia rock formations, Digya national park, Mframabuom caves and lake Bosomtwi, craft villages (like Ahwiaa, Ntonso, etc). Asantemanso village Kumawu town, Kentinkronu shrine, Adarko Jarchie shrine, Ejisu Besease shrine, Patakro shrine and a

host of others. Specific Tourism Potentials and Sculptures promoted The Ashanti Region is a great area to explore because it has a lot of untapped natural attractions. For birds and butterflies, the forests are the place to go, while wildlife can be spotted around the lakes and in the nature reserves. The Ashanti Region is the cultural heartbeat of Ghana. "Land of the Golden Stool" expressed in the language, passage rites, festivals, cuisine and ordinary day-to-day activities. The scenic and hilly capital city of Kumasi is a vast tropical rainforest belt, dominated by impressive buttress rooted forest giants, alongside large cocoa farms and picturesque hillside settlements. Beautiful weather; chilly in the mornings, bright, clear and sunny in the afternoons for most part of the year and cool nights provides ideal conditions for visitors to experience this exciting colorful world of hearty hardworking people. Ashanti is also home of the most important gold mine in Ghana at Obuasi (50km south-west of Kumasi). Surface visits can be arranged, and the town still has air of the gold rush days of the 1890s.Throughout Ashanti (and especially in Kumasi) one will find welcoming hotels and restaurants, in the main towns, nightlife and entertainments are first class. Sporting facilities are available in the urban areas, while exciting fishing can be enjoyed in our lakes and rivers, for example River Offin, River Pra etc. To discover the traditional heartland of Ghana, a visit to Ashanti is a must. (Accessed 2009 August 11). According to the Ghana Tourist Board Directory (1998), visit to Ashanti is emphasized because of these very interesting places to be such as Kumasi (being the capital of the Region). Manhyia Palace Museum Centre for National Culture The Prempeh II Jubilee Museum Kumasi Fort & Military Museum Okomfo Anokye Sword the Akwasidae Ceremony Traditional Street sculptures Komfo Anokye sword The unmovable sword of Komfo Anokye remains in the grounds of the Okomfo Anokye Teaching Hospital, where he pushed it. It is believed the Okomfo pronounced that no one would be able to remove the sword,

and so it has remained in that state in spite of many attempts. This is regarded as one of the main attractions found in the Ashanti Region of Ghana. Oral literature has it that the planting of the sword by Okomfo Anokye signifies the unity of Asante in which its removal can be detrimental and can cause disunity amongst them. The Researcher believes that when this site is conserved properly it will attract tourists so that the country and for that matter Ashanti Region can earn revenue for development and it will also be used for historical documentation. Manhyia Palace the Manhyia palace-the official residence of the "Asantehene" (Asante's king) has a large courtyard with highly decorated gardens and paths. There are peacocks that grace the gardens. In modern times, the palace has been seen as being utilized for other functions rather than has been branded as the official residence of the "Asantehene". The Researcher is of the view that when the Palace which is regarded as the residence of the Great King is promoted it will serve various purposes and also attract more tourists and earn the country and the Ashanti Kingdom more revenue to improve on infrastructure. As part of its socio-cultural functions, former Prempeh II palace has been used for a museum where tourists pay a fee to tour the place. For the purpose of this study, Manhyia palace as a tourism potential functions in the realm of residence for the Great King, Otumfuo Osei Tutu II, administrative offices for the Asante Kingdom. It also has a cultural significance where by the sculptural pieces such as the stool, linguist staff and the host of others combined together to attract visitors from all walks of life. The palace is also opened to the general public for educational tour in which the rich culture or history of the Asantes are delivered in the form of a lecture to visitors or guests to the place. To crown it all, it needs pointing out that the palace also serves as preservation of cultural heritage of the Asantes in the sense that most of the cultural products depicting the life styles, behaviors, precepts, and even practices of Asantes are held in high esteem in the palace.

(Accessed 2009 August 11). Royal Mausoleums. These final resting places of Ashanti Royalty can be seen at Bantama and Breman (a suburb of Kumasi) and may be visited with consent of the Manhyia Palace. The site has been considered over the years as a place of conservation for all the past Kings who ruled the Ashanti kingdom. The names of the past kings are embossed on their stools. Significantly prior to the enstoolment of a King for the Kingdom, the prospect is send to the royal mausoleum to choose a name among the dead heroes also known as the past Kings. The researcher is of the view that the stools also being considered as sculptural in nature are helping in choosing names for prospective Kings. (Accessed 2009 August 11). The Crafts and Craft Villages of Ashanti These crafts villages surrounding Kumasi where they specialize in the production of special crafts. These include: Bonwire - (18km North East of Kumasi) noted for Kente weaving; Pankrono- (3km North of Kumasi) Pottery; Ahwiaa (6km North of Kumasi) Wood carvings; Ntonso - Adinkra cloth making Asuofia/Asamang (Barakese Road) beadmaking ;Ampabame Krofrom (10km from Ahodwo) Brass smithing, Goldsmiths and Silversmiths can be seen in Kumasi. The centre has several functions to perform to the people of Ashanti and they are as follows: creating of job opportunities for the carvers, tourist site attracting tourist who also bring in foreign exchange into the Region and for that matter the country as a whole. It also exists to provide sculpture pieces to the Ashanti Kingdom in the form of stools, linguist staffs, drums and used for various purposes including interior and exterior decorations. They also portray Ghanaian culture, traditions, and beliefs. Pankrono pottery Pankrono is located 8 km on the Mampong Road. Renowned for its distinctive and colorful pottery, created through transitional process without the use of the potter s wheel. It needs to be mentioned that regular training of the people who are engaging in this trade is important since it will enhance the upgrading of their skills in producing the works. Again, regular

training of these people who are mostly old women will bring about empowerment which is a necessary cog in the promotion of the trade in this global market. New and modern techniques can also be introduced to them. The current researcher is of the view that as a tourism potential, Pankrono pottery exists to provide jobs to the makers of the pottery, income earning venture, foreign exchange in the realm of tourist being attracted to the place. (Accessed 2009 August 11). Bobiri Forest Butterfly Sanctuary Bobiri is located 20km on the Kumasi - Accra highway, a quiet research centre for the Forestry Research Institute showcasing an arboretum, forest hiking trails and a butterfly sanctuary. Lodging, guiding and interpretative materials are available. All the gift of nature such as plants and animals otherwise known as flora and fauna, water bodies are being conserved in this site. The researcher is of the view that the sanctuary attracts quite a number of visitors and to help promote tourism and sculpture these craftmen can exhibit their works at this site to enhance the tourism industry, furthermore, apart from site seeing tourists can acquire or purchase souvenirs instead of going to the major exhibiting centers to get souvenirs. (Accessed 2009 August 11). Bomfobiri Wildlife Sanctuary the site is located about 30km from Kumasi. It covers an area of 53km2. It is to the West of Mampong hills. Among its protected species, Bomfobiri Wildlife Sanctuary takes pride in housing the rare bare headed rock fowl. It is showcase of a rare tropical landscape. Assistance and clearance is available at the Wildlife Division Office. [(accessed 2011 January, 17) Digya National Park The Digya National Park was gazette in 1971 and covers an area of 3,478 km2 of undulating terrain with sandstone inselbergs. It is situated on the western bank of the Volta Lake. Guinea savanna woodland predominates with gallery forest along the major lines. The Park supports at least six primate species including black and white colobus, elephants and a variety of antelopes. Have at least six primate species, black and white colobus monkeys and

baboons, elephants and a variety of antelope species, crocodiles, buffalos, water bucks, hartebeests, warthogs, Manatee and clawless otters and are also reported to be present.(accessed 2011 January, 17). The park itself is serving as a recreational facility to holiday makers such as tourists, newly wedded couple etc. Physical appearance of most of the animals found at the park such as their shapes, forms, color, height, etc. normally provide source of inspiration to sculptors in their quest of carving to tow such lines. This site also serves as an educational facility both for students and tourists for them to study and know about the history. It is also serving as a tourism potential where foreign exchange is generated for the Region and country as a whole. Kogyae Strict Nature Reserve the Kogyae Strict Nature Reserve lies in the Ashanti Region of Ghana which falls in the forest zone. It borders two traditional areas of the Region, the Kumawu and Kwamang traditional areas. The area stretches along the Afram plains of Ghana, a wide expanse of flat arable land. The geographical location of the area places it in the traditional zone, separating the Southern forest from the Northern savanna Regions. The Kogyae Strict Reserve is a natural preservation area set up to protect the ecology, check the downward drift of the savanna grassland and to promote scientific research particularly on how nature revitalizes itself after disasters. The area therefore is held as a sacred place for both traditional areas and each lays claim to it. Economically the area is very fertile and constitutes a break on the Northern savanna. Besides, being part of the Afram Plains, it constitutes a major bread basket of the country, and forms a gate way to the larger plains. This nature reserve protects about five species of monkeys. (Accessed 2011 January, 17). Owabi Forest Reserve and Bird Sanctuary a bird Sanctuary located near Kumasi. It protects the catchment area of one of the dams use for water supply to the Kumasi metropolis. Until the construction of the Barekese Dam in 1971, Owabi was the only source of water to Kumasi. Owabi

Wildlife Sanctuary is the smallest of 4 Wildlife Protected areas in Ghana. It is 13km² in size, and lies approximately 23km northwest of Kumasi. It has an inner Sanctuary of about 7km, which surrounds a lake, formed by the damming of the Owabi River in A plantation of an exotic species, Cassia siamea, covers about 10% of the area. The rest consist of secondary vegetation and small areas of riverine forest and aquatic vegetation (accessed 2009 July, 26), (accessed 2011 January, 17).

2.20 Wood Mills in Kumasi

According to Paulus (2019) before colonization of the gold coast, trade was mainly local. Thus, timber was then used basically for the construction of buildings. It is also recorded that although small quantities of hardwood were shipped towards Europe during colonial time, these could not be described as a comprehensive export activity. As a matter of development and economic expansion, it is recorded that "after 1946, when exploitation of timber started to expand in Ghana due to the introduction of roads, railway and the timber truck" (Paulus, 2019).

2.21 List of some Sawmills in Kumasi and their export strength as at 2021

Table 2.4: List of some sawmills in Kumasi and their export strength as at 2021

Company	Location	Export volume(m3)
1. Bibiani Logging and Lumber Co. Ltd.	Kumasi	6.339
2. Logs and Lumber Ltd.	Kumasi	21.767
3. A.G. Timbers Ltd.	Kumasi	10.080
4. Kumi and Co Ltd.	Kumasi	8.530
5. Ahwia Wood Products Ltd.	Kumasi	1.596

6. Naja David Veneer & Plywood Ltd.	Kumasi	9.511
7. Sunstex Company Ltd.	Kumasi	1.620
8. SKOD Timbers Ltd.	Kumasi	1.243
9. Samartex Timber & Plywood Ltd.	Kumasi	26.244
10. Swiss Lumber Sawmill Ltd.	Kumasi	4.674
11. John Bitar & Co. Ltd.	Kumasi	27.541

This indicated that pressure on forestry resources comes along with economic expansion. Paulus (2019) reviewed that the reason why most of the Sawmills are located in Kumasi is the fact that Kumasi has developed during the years into the central timber city of Ghana. Back in 1989, the sawmills in the country numbered about one hundred and nine (109) including nine (9) ply mills and thirteen mills which added to the inevitable production of large volumes of wood waste annually (Appiah, 2016).

During the period between the 1998-1990, the Ghanaian economy had reached a state of virtual collapse caused by falling cocoa prices, inflation and political instability. The government of Ghana in an attempt to rescue the situation had earlier introduced the Economic Recovery Programme (ERP) in 1983. The account rendered by the Economic Recovery programme (ERP) alluded to the fact that the economy of Ghana extensively fed on forestry resources thus, contributing to its depletion because of the imbalances in the rates of extracting and resuscitating the resource. This saw to the expansion of timber exploitation and the export of logs because it was the fastest way of earning foreign exchange. By 1990 Ghana had lost more than 80% of its original forest cover (from 8 million to 1.6 million hectare) to the expanding sawmill industry. Economic Recovery Programme Report (2013).

Amongst the many ways through which Ghana's timber industry has grown was the introduction of The Ghana Investment Code. This was introduced in 1985 and it allowed 25% reduction on timber export taxes for lumber and value added products. As a result this made many foreign investors invest in the Ghana timber industry (Paulus, 2009). This influx of foreign investors in the industry may still have kept its dominance till date. Forestry Outlook Study for Africa (FOSA) Country report 1992 Ghana.

According to Hansen (2017), the growth of Ghana's timber industry is on continuous ascendancy. Paulus (2019) review of Ghana's timber industry recorded 105 registered mills: 5 big scale multi-nationals, 25 medium scale and 75 small scale companies" active on the export market as at 2021. Increase in the number of timber firms has also increased the country's total logging operations. Currently, official estimates suggest that Ghana's total logging is proceeding at about 4 metric tons per year. This is alarming because it is four times the sustainable rate. According to (FAO, 2010) forest lost between 1990 and 2000, and 2000 and 2005 were 135,000 and 115,000 ha, respectively. Excessive logging is among the factors attributed to the high rate of deforestation in Ghana. The main timber species used for production by these mills are; Ceiba, Ofram, Wawa, Koto and Mahogany (trade names).The formal timber industry contributes about 6% to Ghana' Gross Domestic Product (GDP) and directly employs about 100,000 people (Marfo, 2010).

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The methodology for this research work considered the research design, research approach, population, sampling technique, research instrument for the study, data collection procedure, method of data analysis as well as ethical issues

3.2 Research Design

The research adopted cross-sectional survey design for the study. According to Neumann, (2000) cross-sectional surveys are appropriate for situations where the data to be collected are based on self-reported beliefs. Besides, it enables the researcher to collect data and compare many different variables at the same time without manipulating the study environment.

3.3 Research Approach

The research adopted deductive and inductive research approaches in this study. Deductive research approach is a logical procedure in which the conclusion is dependent on the concordance of multiple premises which are considered to be as true. Wilson (2010) indicated that deductive approach in research is concern with "developing a hypothesis (or hypotheses) based on existing theory, and then designing a research strategy to test the hypothesis. This design according to Gulati, (2009), might be tested to see if there is a relationship or link will be obtained on more general circumstances. Deductive approach can be explained by the means of hypotheses, which can be derived from the propositions of the theory. In other words, deductive approach is concerned with deducting conclusions from premises or propositions.

3.4 Population for the Study

The population used for the study was wood carvers, furniture makers and wood processors within Ahwiaa and Kumasi Cultural Centre in the Kumasi Metropolis of the Ashanti Region.

3.5 Sampling Technique and Sample Size

This part of the study describes the sampling technique and sampling size used for the study. Stratified random sampling technique was used to obtain the sample size from a population of 184 comprising of: wood carvers = 78; furniture makers = 214; and wood processors = 48. A total sample size of 184 was obtained in accordance with the mathematical formula: n = N/ [1+N $(\alpha)^2$] where n = sample size; N = sampling frame; α = confidence level (0.05) (Adei & Kunfa, 2007). The sample size of the study was 184 participants, each group of respondents was then obtained proportionally. The breakdown of the number of participants is as follows: wood carvers = 42; furniture makers = 116 and wood processors = 26.

3.6 Instruments for Data Collection

The instrument employed by the researcher to collect data for the study was questionnaire. This questionnaire was for wood carvers, furniture makers and wood processors and it consists of four sections. The first section dealt with the demographic data of the respondents namely: age, sex, educational background, the kind of operation and working experience of the wood workers. The second part which consists of two sections assessed respondent's views on how to fashion sawdust into boards and blocks. Section 2 evaluated how to use sawdust board or block as carving materials. Section 3 investigated the quality of carved pieces from sawdust blocks/board.

3.7 Validity and Reliability of Questionnaire

A pilot study was conducted at Bonwire wood carvers to assess the validity (internal consistencies) and reliability of the questionnaires in order to enhance its accuracy for assessment and evaluation. Participants for the pilot study were drawn from the wood carving workers at Bonwire. They completed the questionnaire and in addition provided suggestion for its modification to help remove any ambiguity. The reliability of the questionnaire, which was concern with its ability to measure consistently, was determined using the Cronbach's alpha. A Cronbach's alpha value of 0.76 was obtained for the questionnaires used which were considered to be adequate**.**

3.8 Data Collection Procedure

Data for this study which was meant to assess perception of woodworkers on the use of pressed sawdust for carving was collected using five-point likert's scale questionnaires at a single point in time. The questionnaire was administered by the researcher to the participants directly in June 2021. A total number of 184 questionnaires were administered. The questionnaires that were successfully completed were 176 in number (wood carvers = 42, furniture makers = 110 and wood processors = 24). This represents a return rate of about 95.7%. According to Dillman (2000) as cited in Mitchual and Donkoh (2015) a return rate of 70% or more is a true representative sample of the population

3.9 Method of Data Analysis

Statistical software used for the analyses was Statistical Package for Social Scientists (SPSS version 20.0). The data was analysed using descriptive and inferential statistics. The mean and standard deviation of the ratings for each of the items were computed and the mean compared to the theoretical mean rating (assuming normal distribution of responses) to ascertain the respondents' perception on the themes studied. An item-by-item analysis of variance (ANOVA) at 5% level of significance was performed to establish possible significant difference in the respondents' ratings of the factors of this study. P-values lower than 0.05 were deemed significant.

3.10 Ethical Consideration

Ethical issues which were ensured in this study included issues of informed consent, invasion of privacy, anonymity of respondents, voluntarism and plagiarism. The researcher sought the permission of all participants in the research before the conduct of the study (informed consent). Introductory letter was sent to the management of the Ahwiaa timber market and Kumasi Cultural Centre and their approval received before the research commenced. The researcher made prior visits to management in order to pre-arrange data gathering periods. This was to prevent unnecessary interruption in their work schedules thereby invading their privacy. Neither names nor any identifiable information from respondents was taken as a way of ensuring the ethical principle of anonymity in social research. This was to prevent possible victimization of respondents in situations that certain responses may be viewed as injurious to management or colleagues.

While distributing the questionnaire, the researcher verbally informed all respondents who agreed to answer questionnaires that, their participation was voluntary. They could, therefore opt out at any stage of the research process. They could also skip questions they did not know the answers otherwise any guess they made would be taken as a correct answer for analysis if the data. This was just to ensure that the researcher did not breach the ethical principle of voluntarism to participate in social research. Pieces of information cited from earlier studies on occupational health and safety to support analysis of the study were duly acknowledged through both in-test referencing and a bibliography. This was meant to avoid academic dishonesty or plagiarism. Findings cited in the literature review of this study were also duly acknowledged in line with the academic property law.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

The purpose of this study was to assess the perception of the use of sawdust as a substitute for carving material. This section comprises of the result and discussion of the study. The presentation has been done in line with the objectives of the study. The first section deals with the socio-demographic characteristics of the respondents which include: educational background, working experience and the type of operation the workers perform. The second part assessed how to fashion sawdust into blocks and boards to serve as a suitable material for carving. Thirdly, assessed the factors that influence timber species selection for Wood carving works. Also, to carve designed pieces out of sawdust boards and to compare the quality of carved pieces from sawdust boards to that of conventional timber.

4.2 Socio-Demographic Data of Respondents

The socio-demographic characteristics of the respondents that were considered in this study includes: gender, work experience, educational level and the type of operation they perform at the selected centres.

4.2.1 Gender of Respondents

All the participants (100%) involved in the wood operation were males with no female taking part in the wood processing operations. In finding out why there were only males, most of the respondent suggested that due to the physical activities involved in wood processing, females do not prefer taking up such jobs or training. In finding out why there were only males, Jerie (2012), at Mutare-Zimbabwe attributed that to lifting of heavy objects and tedious nature of processing wood.

Gender	Frequency	Percentage (%)
Male	184	100%
Female	0	0
Total	**184**	**100**

Table 4.1 Gender of respondents

4.2.2: Age

Table 4.2: Age category

Age category	Frequency	Percentage
20 – 30 years	19	10.3
31- 40 years	59	32.1
41- 50 years	79	42.9
51- 60 years	20	10.9
Above 60 years	7	3.8
Total	**184**	**100**

Table 4.2 reveals that 79(42.9%) of the respondents were between the age ranges 41-50 years, 59(32.1%) were between the age category 31-40 years, 20(10.9%) were between the age ranges 51-60 years, 19(10.3%) were between 20 - 30 years, while 7 (3.8%) were above 60 years old.

4.2.3: Educational Background

The result on the level of education of the wood processors revealed that, 13 out of 184 respondents representing 6.9% did not have formal education, 122 respondents representing 66.3% have had primary education, 35 respondents representing 19.0% have had through secondary education and 14 of the respondents representing 7.8%

have had their tertiary education. This indicates that the majority of the respondents ended their education at the basic level or primary level.

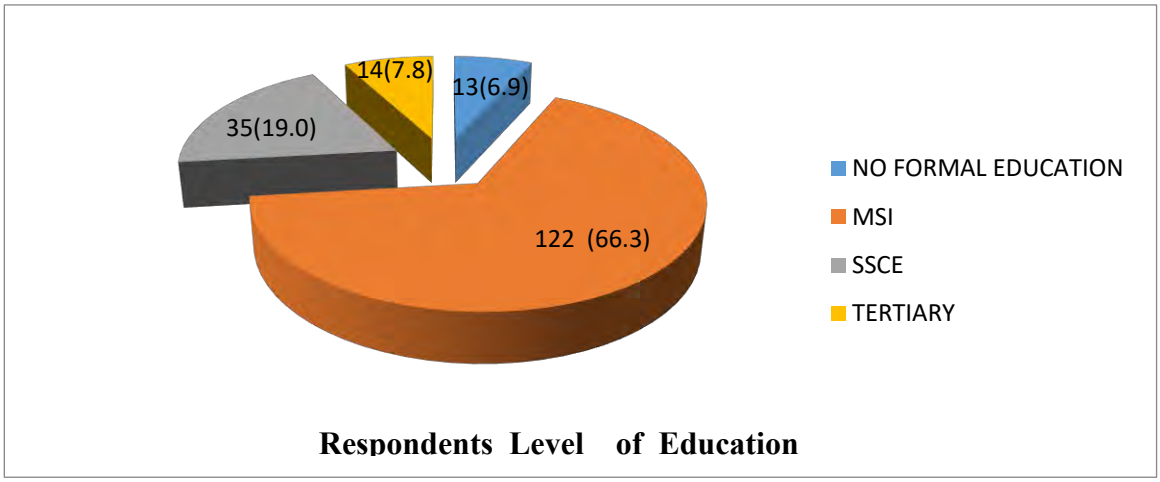

Figure 4.1 Respondent's educational qualification

4.2.4: Kind of operation

Assessment of the five major operations namely: sawing, planning, moulding, sanding, carving that the participant belongs to indicated that, out of 184 participants, 92 respondents representing 50.2% were operating sawing machines, 32 respondents representing 17.3% were operators of surface planner machines, 29 respondents representing 15.6% were operators of moulding machine whiles 14 respondents representing 7.4% were sanding operators and, 17 respondents representing 9.5% were wood carvers. The result on the kind of operation is represented in Table 4.2.

Table 4.2: Kind of operation of respondents

Kind of operation	Frequency (f)	Percentage (%)
Sawing operation	92	50.2
surface planner operators	32	17.3
Spindle moulder operator	29	15.6
Sanding operators	14	7.4
Carving operation	17	9.5
Total	**184**	**100**

This result clearly indicates that, there were more sawmilling operations than any other operation, because sawmilling is the bedrock of every timber processing industry which begins its operations from the forest to the log yard all the way to edging and trimming.

4.2.5: Working experience of the wood workers

Figure 4.1 indicates the working experience of the participant of the study. The result shows that, out of the 184 participant that responded to the questionnaire, 34 participants representing 18.5% indicated that, they have been in the wood processing industry for less than one year, 71 participants which is equivalent to 38.5% have worked for between 1 - 5 years, 46 participants representing 24.9% have worked for between 6 - 10 years, 19 participants representing 10.5% have been in the wood processing industry for between 10 – 15 years whiles the remaining 14 respondents representing 7.6% have been working in the wood industry for more than 15 years.

From the result it could be concluded that majority of the workers have had 1 - 5years working experience. As stated earlier the longer one works at a place, the more experienced he or she becomes. Bello (2010) conducted in a study that the number of years a participant has had on a job could help to reduce the rate at which accident will occur as a result of acquisition of more skills and knowledge.

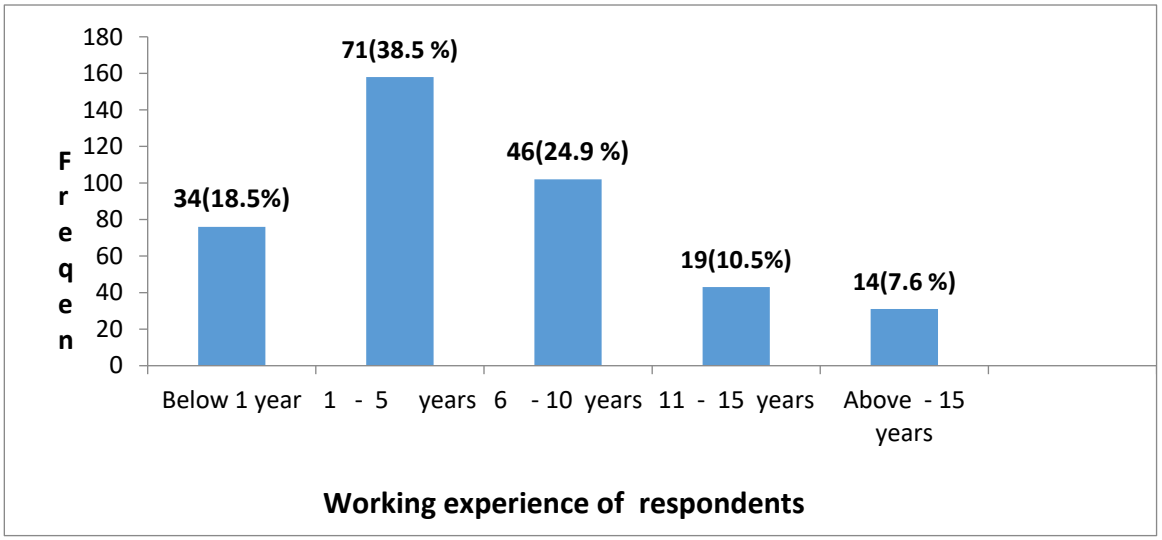

Figure 4.2: The bar chart showing number of working experiences of the wood workers.

4.3 Perception on the use of bonded sawdust as a carving material

This part of the study assessed the perception of the woodworkers on the use of bonded sawdust as material for carving. The result is presented in **Table 4.3.** Six items were assessed using five-point Likert scale with theoretical mean rating of 3.0. Five out of the six items assessed "Sawdust can be molded into different shapes and size", "Sawdust can be obtained in large quantities", "Sawdust board is odourless", "Sawdust when turned into boards may have excellent surface finish" and "Sawdust board is environmentally friendly" had their mean ratings higher than the theoretical mean rating of 3.0. This suggests that the respondents agreed to the statement that sawdust can be molded, obtained in large quantities, is odourless, have excellent surface finish and its environmentally friendly as well. Exception to the above is item "Sawdust has no commercial value" that had a mean rating of 2.02 which is lower than the theoretical mean rating of 3.0. This indicate that, the respondents disagreed to the statement that sawdust has no commercial value. The respondents

further asserted that sawdust has a lot of commercial values since sawdust can be used for manufactured products such as particleboards and briquettes.

Table 4.3 further indicated that the most ranked item was item **# 3 "**Sawdust can be obtained in large quantities" which had mean rating of 4.01 (S.D. = 0.055). This also suggest that majority of the respondents agreed that, sawdust can be obtained in large quantities". This was followed by item **# 1 "**Sawdust can be molded into different shapes and size" ranked second most agreed item, item **# 6 "**Sawdust board is environmentally friendly**"** was ranked third. The least ranked item was item **# 2 "**Sawdust has no commercial value" which had mean rating of 2.02 (S.D. = 0.456).

Table 4.3 Perception on the use of bonded sawdust as a carving material

Item	No	Mean	S. D	Ranking
Sawdust can be molded into different shapes and size	184	3.78	.067	2
Sawdust has no commercial value	184	2.02	.456	6
Sawdust can be obtained in large quantities	184	4.01	.055	1
Sawdust board is odourless Sawdust can be molded into different shapes and size	184	3.46	.061	4
Sawdust when turned into boards may have excellent surface finish	184	3.08	.252	5
Sawdust board is environmentally friendly	184	3.67	.070	3

According to Hoadly (2000) sawdust can be manufactured by spraying wood particles with adhesives, forming them into different shapes and sizes. Marfo (2010) also agreed that sawdust is any wood that has no longer any value at its present location which is classified as wood waste that can be molded into other uses. FAO estimated that wood processing wastes generated in the year 2008 totaled 256,000 m, equivalent to one hundred and twenty-eight thousand two hundred and fifty (128,250) tones, based on

sawn wood production for 2008.In other not to waste the sawdust, it can be used for other items as suggested by Hoadly (2000). This assertion reveals how sawdust, a regenerative material is left to go waste. (Global Forest Product facts and figures 2013). Report by UNDP/World Bank Energy Sector Management Assistance Project on Sawmill Residue utilization (2016) indicated that sawdust alone accounted for 21% of the total residues generated. Australian wooden furniture manufacturing companies report November 2009 reiterated that sawdust is abundantly available at sawmills and carpentry shops. Conner and Bhuiyan (2017) opined that sawdust is odorless. Myers et.al (1991) also agreed that the surfaces of the compressed sawdust can be sanded smooth and ready for use.

On the contrary, the results from Table 4.3 disagree with the findings of the study conducted by Lee et al. (2001) which indicated that sawdust boards are not environmentally friendly due to no-added-formaldehyde which may pollute the environment.

4.4 The factors that influence timber species selection for Wood carving works.

Table 4.4. The factors that influence timber species selection for Wood carving works.

Factors that Influence Species Selection	Mean X	Rank
Wood as building material will be used because of its durability and other mechanical and physical properties	4.77	1st
Quality	4.65	2nd
Appearance	4.61	3rd
Processability	4.55	4th
Type of product	4.52	5th
Availability	4.48	6th
Price	4.32	7th
Affordability	4.22	8th

Thickness sizes	4.17	9th
Sustainability	4.14	10th
Suitability	4.12	11th
Informed decision	4.07	12th
Area of usage	3.96	13th
Expert advice	3.84	14th

Source: Field survey, (2022),

The study results show that an average (94.1%) of the respondents agreed the factors that influence timber species selection for wood carving works were durability and other mechanical and physical properties (mean score of 4.77, SD - 0.76, ranked 1st), There is therefore the need to increase utilization of a wide number of species, especially lesser - used species (LUS) to help prevent creaming for the few traditional high value species. Durability, appearance, quality and processability were the most influential factors for the specification and selection of the species. Affordability, area of usage and informed decision were the least influential factors. Type of product, expert advice, suitability, sustainability and availability were all fairly influential factors for specification and selection of the species.

Quality (mean score of 4.65, SD - 0.79, ranked 2nd), Appearance (mean score 4.61, SD - 0.83, ranked 3rd), Processability (mean score of 4.55, SD - 0.87, ranked 4th), Although all the factors were of significant importance in the specification and selection of the timber species, factors like appearance, price and availability were all influential as the case of Zziwa et al. (2009). Durability was ranked as the most influential factor amongst all the factors. A probable interpretation is due to knowledge on the maintenance incurred on inferior species when used for certain purposes. Ranking order of the factors seems to indicate consumers' preparedness to spend more money and get value in the long run. Another reason for the price being last could be the relatively cheaper

(20-40% cheaper) illegal chain-saw lumber supplied to the markets (Oteng -Amoako et al., 2018).

Type of product (mean score of 4.52, SD - 0.96, ranked 5th), Availability (mean score of 4.48, SD - 0.98, ranked 6th), the study shows that from the many timber species available in Ghana, only few species were found on the market for possible utilization. From the study, out of thirty-two species that were outlined, twenty-two of them were found to be available on the markets.

Price (mean score of 4.32, SD - 1.07, ranked 7th), Affordability (mean score 4.22, SD - 1.23, ranked 8th), this cheaper price of domestic illegal lumber does not motivate producers of legal lumber to sell on the domestic market (Oteng-Amoako et al., 2008).

Type of product, expert advice, suitability, sustainability, availability, area of usage and informed decision which are all very important factors for the specification and selection of timber species for furniture and joinery production faired considerably influential from the study.

Thickness sizes (mean score of 4.17, SD - 1.28, ranked 9th), Seven common sawn lumber sizes and the actual sizes on display at the markets showed that thickness sizes were less by 5mm for four sizes. The remaining three thickness sizes met the standard sizes. The width sizes for all the observed pieces were less by 5-20mm for all the seven sizes. It was concluded that the trend of availability of the species on the markets is attributed to the knowledge on the utilization of the species and the easiness to obtain by the dealers whiles most wood users buy lumber without checking if the sizes are actual as indicated.

Sustainability (mean score of 4.14, SD - 1.33, ranked 10th), Knowing what is left of our valuable timber resource can help maintain sustainable use of the resource. There is a need to undertake inventory to know the volume of timber trees and non-forest products

like bamboo and rattan that currently exist in our forest reserves. Application of prudent silvicultural treatments of saplings and immature trees can increase the quality and quantity of saplings and enhance their natural regeneration and growth to maturity. Likewise, the quantity and quality of regenerated forest can increase through appropriate enrichment planting (Ghana Forestry Commission, 2009).

Suitability (mean score of 4.12, SD - 1.35, ranked 11th), Informed decision (mean score of 4.07, SD - 1.39, ranked 12th), The reluctance to use a great variety of timbers, especially the lesser-used species, may be attributed to several factors among which are: traditional marketing practice, lack of guidance on selection for a purpose, familiar species and risk involved (Ayarkwa, 2018). Making informed and responsible choices when selecting and purchasing wood for use is one of the most important things one needs to do to get value for the money spent. Preferences are typical for consumer markets. They influence what consumers would buy and relate to the material used for product production, its quality, appearance and functionality (Paluš et al., 2012).

Area of usage (mean score of 3.96, SD - 1.46, ranked 13th), and Expert advice (mean score of 3.84, SD - 1.49, ranked 14th). Results from the analysis indicate that all the twelve factors that were put up for consideration with regards to their influence to the selection of the species, all of them were influential towards the selection of a particular species for usage. However, durability, appearance and quality were the most influential in that order. Affordability, area of usage and informed decision were the least influential factors. Type of product, expert advice, suitability, sustainability and availability were the other influential factors.

The study depicts mean ratings of factors that influence the selection of timber for furniture and joinery products at the two timber markets. Wood as building material

will be used because of its durability and other mechanical and physical properties (Paluš et al., 2012).

4.5 The use of sawdust board or block as carving materials

This part of the study assessed the perception of the respondents on the use of sawdust board or block as a carving material in the carving industry. The result is presented in **Table 4.5**. The data was collected using a five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = sometimes, 4 = agree and 5 = strongly agree). Theoretical mean rating of 3.0 was obtained and compared to the mean ratings of each of the item analyzed

Table 4.5 Results from respondents on using sawdust board or block as carving materials.

Item #	Item	Mean	S.D.	Ranking
1	Carving an artifact from sawdust particle board requires a sharpened edge tool	4.03	0.34	1st
2	Sawdust board/block is light in weight	3.57	0.41	2nd
3	Sawdust board/block have good workability	3.09	0.50	4th
4	Carving an artifact from sawdust particle board is easy to work with	2.14	0.65	6th
5	Carvings from sawdust particle board are beautiful	2.67	0.59	5th
6	Carvings from sawdust particle board do not produce waste	3.56	0.41	3rd
	Resultant mean rating	3.18	0.48	

Table 4.5 shows the responses of the respondents on whether sawdust board/block can be used as carving material. Most of the respondents agreed that sawdust block/board can be used as carving material because carvings from sawdust board is easy to work with (3.96) it is light in weight (4.5) the boards have good workability(4.03) and that one has to have sharpened edge tools to get good results (4.53).

However they disagreed that artifacts made from sawdust board look beautiful as compared to artifacts from solid wood (3.76) and that carving from sawdust board do not produce waste (3.46).

The results from the respondents agree with literature. According to Rowell (1995) sawdust board have good workability that can be a substitute material for wood workers in other to save our forest and also save the environment from pollution.

Myers et.al (1991) also agreed that the surfaces of the boards can be sanded smooth and ready for use. Leohnertz and Cooz (1998) stated that good saw teeth can cut well in particle boards. Moradpour et al. (2016) also reiterated that good cutting forces depended on sharpened teeth, speed of cutting and the cutting rate.

Amoh (2009) stated sawdust boards are soft, light in weight and not durable. They are promptly affected by shrinkage while drying pests attack them easily and are mostly used for making stools, bowls, combs, linguist staffs, Akuaba doll and totemic animal forms. Again Dhai (2012) opined that sawdust composite has advantage of producing a product that is easy to work with. Rowell (1975) revealed that the natural reactivity of lignocelluloses can be utilized to enhance their properties with the resulting material being superior in terms of performance and versatility. Also the results from the respondents' showed that they disagreed that carvings from sawdust particle board do not produce waste as solid wood, Although carvings from sawdust do produce waste but its waste produced is minimal as compared to that of solid board.

4.6 The quality of carved pieces from sawdust blocks/board

Table 4.6 Results from respondents on the quality of carved pieces from sawdust blocks/board

Item #	Item	Mean	S.D.	Ranking
1	Sawdust particle board size and shape has influence on the strength	3.76	0.34	2nd
2	Sawdust board has a very good bonding property	4.02	0.28	1st
3	Sawdust boards has its major constituents as fibers and fiber bundles	1.67	0.78	6th
4	Carvings from sawdust particle board are durable	3.04	0.45	4th
5	Carvings from sawdust particle board will not rot, crack, warp	3.66	0.39	3rd
6	Carvings from sawdust particle board are 100% termite and water proof	2.03	0.61	5th
	Resultant mean rating			

Table 4.6 Represent the responses of the respondents on the quality of carved pieces from sawdust blocks/board. From the results most of the respondents agreed that Sawdust particle board size and shape has influence on the strength (4.03) Sawdust board has a very good bonding property (3.76) Sawdust boards has its major constituents as fibers and fiber bundles (3.9). However, they were not sure that carvings from sawdust particle board are durable (3.2) and carvings from sawdust particle board will not rot, crack, warp (2.63). Again, some of the respondents disagreed that carvings from sawdust particle board are 100% termite and water proof (1.9).

The results from the respondents agree with literature. According to Kent and Riegel (2007) stated that the strength of the product is determined by the adhesive used and not the fiber used, although the size and shape have influence on the strength

Myers *et al.* 1991 also stated that the process of stress-transfer is complete if there is good bonding between the particles and the matrix. Coupling agents are therefore essential to ensure suitable bond formation between the particles and the matrix. Coupling agents may physically or chemically improve the bonds. Bodig and Jayne (1982) opined that it has its major constituents as fibre and fibre bundles**.**

The results from the respondents again shows that some of the respondents are not sure with that carving from sawdust particle board are durable according to Amoh (2009) that carvings from sawdust particle board are not durable and they are promptly affected by shrinkage while drying and pests attack them easily. The respondents disagreed with the literature according to Adu-Agyem (1990) stated that sawdust board does not crack, warp and rot easily but when drying if proper care and procedure is followed it will warp and cracked. The respondents disagreed to the carvings from sawdust particle board are 100% termite and water proof according to Tout, Bomba et al (2014) stated that there is a water-resistant version of PVA adhesive in the sawdust board that can withstand moisture and mildew but will still dissolve if submerged in water, their responses goes well with literature because of the wood particle (sawdust) and the adhesives component in the product cannot have 100% termite and water proof.

4.7 Observation of Curved Articles from Sawdust Board

The carve articles were given to 15 respondents to observe and pass their comments. All the fifteen (15) respondents agreed that the carved articles look nice and beautiful but they found the sawdust particle frilling and they also observed that the carve article did not look heavy as compared to carvings from solid wood. They all agreed that something should be done to the sawdust boards to prevent it from frilling.

Most of the respondents (12) representing 80% were of the view that they would not want to use sawdust board for carving because of the frilling nature. However they were of the view that if something could be done to prevent the frilling then they would go for the sawdust articles. They were of the view that since the adhesives used to bond the sawdust into boards was not water resistant or water proof if the articles are left in the rain or if water is poured on any of the articles they would not be able to withstand

the test of time rather they would spoiled. They were of the opinion that the sawdust boards should be bonded by water resistant adhesives to make them durable.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATION

5.1 Summary of Findings

The purpose of this study was to assess the perception of the use of sawdust as a substitute for carving material. The research adopted cross-sectional survey design for the study. The research adopted deductive and inductive research approaches in this study. The population for the study was 340 which includes: wood carvers, furniture makers and wood processors within Ahwiaa and Kumasi Cultural Centre in Kumasi Metropolis in Ashanti region. Stratified random sampling technique was used to obtain the sample size from a population of 340 comprising of: wood carvers = 78; furniture makers = 214; and wood processors = 48. A total sample size of 184 was obtained. Questionnaire was the main instrument used to gather primary data. Statistical Package for Social Scientists (SPSS version 20.0) was used to analyse data. The data was analysed using descriptive and inferential statistics.

5.2 Major Findings

Although bonded sawdust could be carved just as wood, experiment revealed that only extremely well sharpened tools could do the carving to expectation. Any blunt tool was found to peel the mould off rather than carved it. It was revealed in the research that pieces carved out of bonded sawdust would be best for interior use than exterior usage. This was because bonded sawdust could not withstand rain as compared to wood. Bonded sawdust that came into contact with rain were susceptible to reverse to their original state if handled well and left to dry. It was however observed that if a mould is left in continues rain, the individual particles tend to flake off.

The study results show that an average (94.1%) of the respondents agreed the factors that influence timber species selection for construction works were durability and other mechanical and physical properties (mean score 4.77, SD - 0.76, ranked 1st), Quality (mean score 4.65, SD - 0.79, ranked 2nd), Appearance (mean score 4.61, SD - 0.83, ranked 3rd), Processability (mean score 4.55, SD - 0.87, ranked 4th), Type of product (mean score 4.52, SD - 0.96, ranked 5th), Availability (mean score 4.48, SD - 0.98, ranked 6th), Price (mean score 4.32, SD - 1.07, ranked 7th), Affordability (mean score 4.22, SD - 1.23, ranked 8th), Thickness sizes (mean score 4.17, SD - 1.28, ranked 9th), Sustainability (mean score 4.14, SD - 1.33, ranked 10th), Suitability (mean score 4.12, SD - 1.35, ranked 11th), Informed decision (mean score 4.07, SD - 1.39, ranked 12th), Area of usage (mean score 3.96, SD - 1.46, ranked 13th), and Expert advice (mean score 3.84, SD - 1.49, ranked 14th).

5.3 Conclusion

The local timber industry in Ghana has for some time now experienced major challenges that have subjected the sector to severe pressure regarding raw material unavailability and a struggle for efficient use of the limited available timber. This situation has come about as a result of the decline of Ghana's timber resource making timber difficult to come by and very expensive on the local timber market. Local consumers out of unawareness and scarcity end up using inferior timber for superior jobs and vice versa. In spite of the countless number of environmental campaigns, both locally and internationally, the rich forest lands continue to deplete at a threatening speed (Okra 2012). The timber industry is widely opening up and as a result, it is adversely adding to deforestation. The current research was based on the use of bonded sawdust as a substitute material for carving.

The factors that influence timber species selection for carving works were durability and other mechanical and physical properties, quality, appearance, processability, type of product, availability, price, affordability, thickness sizes, sustainability, suitability, informed decision, area of usage, and expert advice.

The following conclusion were also made from the results:

1. That sawdust could be used as carving material and fashion into blocks and boards to serve as a substitute material for carving.
2. That sawdust board could be used as carving material.
3. That the quality of carved pieces from sawdust boards could be compared to solid boards.

5.4 Recommendations

Having undertaken a thorough study on the viability of the bonded sawdust as a substitute material for wood carving, the researcher recommends as following:

- A planned orientation programme should be organized for wood carvers to acquaint them with the use of bonded sawdust as a substitute material for carving.
- A special education on the relevance of the use of bonded sawdust as a substitute material to the tourism and other stake holders responsible for the preservation of the Ghanaian cultural heritage.
- Pieces carved out of sawdust particle boards would be best for interior use than exterior usage.
- The material requires a well sharpened tools to work with
- Wood carvers should adopt the use of bonded sawdust to save the forest and environmental pollution.
- The use of bonded sawdust as a substitute material should be introduced in all sculpture departments in Senior High Schools.

- Exhibitions should be organized so that artifacts carved from bonded sawdust be showcased to the public.
- Further research works should be done on this topic to totally exhaust the viability of sawdust.
- Art faculties in the various universities across the country should encourage students to further undertake research works on sawdust.
- Future researchers should increases the sample size to be able to cover a wider population and to be able to ascertain the impact of the use of bonded sawdust as a substitute material for carving

5.5 Suggestions for Future Research

The researcher suggests that a similar study should be conducted to investigate the natural durability of wood spices used for carving and its ability to resist the attacks of foreign organisms including fungi, insects and marine borers.

REFERENCES

Acquah, T.E. (1998).*the potential for Ghana's woo/wood products in the US market.* University of Maryland and Eastern Shore. USAID Africa Bureau Information Centre.

Adu-Agyem, J. (1990). *Concepts of Aesthetics, Appreciation and Criticism among Indigenous Asante Carvers*. M.A thesis. KNUST, Kumasi: Department of Art Education.

Amoh, E. (2009). *Ahwiaa wood carving industry: new trends and their implications for art education,* MA thesis. KNUST, Kumasi: Department of Art Education.

Appiah, S. (1997). *A complete guide to graphic design.* Accra. Pentecost press ltd.

Asabere, A. (2011). *Developing a criteria for assessing the quality of skins and hides for indigenous leather production in the Kumasi metropolis.* M. A. Thesis KNUST, Kumasi: Department of Art Education.

Asiama, F. (2008). Ghana: Wood carving industry under threat.

Adebara, S. A., Hassan, H, Shittu, M. B. & Anifowose, M. A. (2014). Quality and Utilization of Timber Species for Building Construction in Minna, Nigeria. *The International Journal of Engineering and Science, 3 (5):* 46-50.

Ametsistsi, G. K. D., Kyereh, B., Duah-Gyamfi, A. & Agyeman, V. K. (2019). Quality control and Standardization of Ghanaian Wood Products. Identify local market requirements for timber and wood Products and priority areas for standards and grading rules development. *ITTO Project PD 318/04 Rev. 2. (I)* (Activity 2.2).

Ayarkwa, J. (2018). New marketable Ghanaian timber Species for furniture and construction. *Wood News Jul-Sep 98;* 13- 18.

Avison, D. (1999). Action Research. Communication of The ACM vol.42 No1 pp.1-4

Bentum, A.L.K. (2017). *Local Substitute for Foreign Timbers*. Information Bulletin No.7 Forestry Products Research Institute, Kumasi, Ghana.

Boateng, W. (n.d). Carving traditions in Ghana. National Commission on Culture. UNESCO Ghana.

Brent, E. (1994). Wastes into Wood: Composites Are a Promising New Resource Environmental Health Perspectives Vol. 102, No2 pp.168-170.

Brydon-Miller, M. (2003). *Why Action Research?* USA: University of Cincinnati.

Campbell, R. N. and Clark, J. W. (2010). Decay resistance of bald cypress Heart wood. *Forest Products Journal X (5):* 250-258.

Campbell, D. & Stanley, J. (1963). *Experimental and quasi-experimental designs for research*. Chicago, IL: Rand-McNally.

Carl, C. (1986). *Wood particleboard and flake board*: Types, grades, and uses. Forest products laboratory, Madison, WI.

CIFOR Infobrief No. 1 (2002). Planning for woodcarving in the 21st century. Centre for International Forestry Research, UK.

Dei, J. S. (1990). *Deforestation in a Ghanaian Community, Anthropologica*. 32 (1): pp. 3-27.

Dinwoodie, H. B. (1989). *Creep in Chipboard*. England: Aylesbury.

Domson, O. (2007). *A Strategic Overview of the Forest sector in Ghana*. USA: Louisiana State University Press.

Duku, M.H., Gu, S. & Hagan, E.B. (2011). *A comprehensive review of biomass resources and biofuels potential in Ghana.* California: Wadsworth Publishing Company.

Eaton R. A. and Hale, M.D.C. (2013). *Wood Decay, pests and protection.* Chapman and Hall, University Printing house, Cambridge. 546pages

Edmonton (2017). *Wood Decay, pests and protection.* Chapman and Hall, University Printing house, Cambridge. Pages 313.

Effah, B, Osei, J. K. & Antwi, K. (2013). Examining the physical properties and within tree variability in the physic al properties of two lesser - known timber species in Ghana. *International Journal of Science and Technology, 3 (8):* 328-332.

Eisa, M. (2002). *Municipal solid waste management in Asia and Africa:* A comparative analysis (UNIDO).

Fergusson, K. (2010). *Ghana Hardwoods*. AS. Worth, London, UK.

Given, M.L. (2008). *Sage Encyclopaedia of Qualitative Research Methods* (Vol. 1&2). London: Sage Publications.

Gribbons, B. & Herman, J. (1997). True and quasi-experimental designs. *Practical Assessment, Research & Evaluation, 5*(14). Retrieved January 23, 2012

Haygreen, J. G. and Bowyer, J. L. (2016). Forest Products and wood science. Third Edition. Iowa State University Press. Pp.243-247.

Hesse-Biber, N.S. (2010). *Mixed Methods Research: merging theory and practice.* New York: The Guilford Press.

Hudson, J. J. (2011). *Discourse With Foase Traditional Wood Carvers*: Implications for Art Education, MA thesis. KNUST, Kumasi: Department of General Art Studies.

ITTO (2012). Technological profiles of selected species –Ghana. ITTO PD 179/91 document.

Marfo, E. (2010). *Chainsaw Milling in Ghana:* Context, Drivers and Impacts. Tropenbos International, Wageningen, the Netherlands.

Kollman, F. F. P. and Cote, W. A., (2014). *Principles of Wood Science and Technology.* Volume 1: Solid Wood. Springer-Verlag, Berlin, Heidelberg, New York, Tokyo, 592pp.

Larson, B. (1997). Structural probing and mutagenic analysis of the stem-loop required for Escherichia coli dnaX ribosomal frameshifting: programmed efficiency of 50% J.Mol.Biol. 271:47-60.

Marfo, E. (2010). *Chainsaw Milling in Ghana: Context, drivers and impacts*. Tropenbos International, Wageningen, the Netherlands.

Mellerowicz, B.M. & Sundberg, B.W. (2001). Unravelling cell wall formation, the woody dicot stem. *Plant Molecular Biology.* Forest products laboratory, Madison, WI.

Mohamed, E. & Visvanathan, C. (2002). M*unicipal solid waste management in Asia and Africa:* A Comparative Analysis (UNIDO).

Moses, H. (2011). *Duku* a, b, Sai Gu a, Essel Ben *Hagan* b a School of Engineering Sciences **.** *Renewable and Sustainable Energy Reviews 15,* 404–415

New Phytologist, Vol. 164, No. 1 (Oct., 2004), Blackwell Publishing.

Okra, E. (2002). *the growth of wood carving industry in Ghana and its threat to selected tree species.* Lund University, Lund, Sweden.

Ott, L. (2001). *An introduction to statistical methods and data analysis*. USA: Texas A&M University.

Owusu, J.G.K. (2003). *Policies supporting the selection of system of natural forest management in Ghana* (vol. 2). ITT project PD4198.

Oteng - Amoako et al. (2018). Timber Industry Restructuring Group Final Report. Voluntary Partnership Agreement.

Ofori, J. (2010). *Preservation of hardwoods in relation to treatment techniques*. PHD Thesis. Timber Technology Research Laboratory. Imperial College Of Science and Tech. London. Pp. 4-5.

Panshin, A. J. and C. de Zeeuw. (2010). *Textbook of Wood Technology.* Vol. 1 4th Edition. New York. McGraw-Hill Books Company. Inc. New York. Pg. 185-200.

Paluš, H, Maťová, H. & Kaputa, V. (2012). Consumer Preferences for Joinery Products and Furniture in Slovakia and Poland. *ACTA FACULTATIS XYLOLOGIAE 54(2):* 123 -132.

Papadopoulos, A.N. & Gkaraveli, A. (2003). *Dimensional stabilisation and strength of particleboard by chemical modification with prop ionic anhydride*. Springer-Verlag.

Papadopoulos, A.N., & Traboulay, E. (2002). *Dimensional stability of OSB made from acetylated fir strands*. Holz Roh- Werkstoff.

Park, G. (2001). *Optimized material composition to improve the physical and mechanical properties of extruded wood-plastic composites.*

Paulus, W. (2009). *The Ghanaian timber industry and the voluntary participation agreement.* Hogeschool Van Hall Larensien Velp, the Netherlands.

Pilate, G. (2004). Tension Wood as a Model for Functional Genomics of Wood Formation.

Raune, M. J. (2006). *Essentials of research methods: a guide to social science research*. Oxford: Blackwell Publishing

Ross, M. (2004). Art at the Crossroads: The Contested Position of Indigenous Arts in Ghana's Post-Colonial Education Systems. Madison, USA: *Studies in Art Education Association, 45*(2): 117-134.

Rowell, R.M. (1975). *Chemical modification of wood: Advantages and disadvantages*. New Zealand. University of Auckland

Saad, H. (2009). *Environmentally Sound management of Waste in Egypt*: A National review (UNIDO).

Scheffer, T. C., and Cowling, E. B., (2016). Natural resistance of wood to microbial deterioration, *Ann. Rev. Phytopathol, 4 pp* 147-170.

Scheffer and Hopp (2019). *Wood Decay, pests and protection*. Chapman and Hall, University Printing house, Cambridge. Pages 313.

United Nations Economic Commission for Africa (2008). Sustainable Development report on Africa – Five year review of the Implementation of the World Summit on Sustainable Development Outcomes in Africa (WSSD).

William, N. (2001). *Your research project*, (1st ed.) London: Sage publications Ltd.

Wilson, B. J. (2009). Life-Cycle Inventory of Particleboard in terms of Resource Emissions, Energy and Carbon. Department of Wood Science Engineering. USA: Oregon State University Press.

Winandy, J. (1994). Effects of long-term elevated temperature on CCA-treated southern pine lumber. *Forest Prod. J. 44*(6):49-55.

A.H.Conner, M.S.H.Bhuiyan (2017) Module in materials science and materials engineering Tout, Bomba et al (2014) wood adhesives.

Taylor &Francis (2018) Journal of adhesives Vol.94

International Panel Products Symposium, Cardiff, Wales, U.K. January 2007

African Regional Workshop (Conservation & Sustainable Management of trees, Zimbabwe, July 1996)

Zziwa, A, Bukenya, M., Sseremba, O. E. & Kyeyune, R. K. (2016). Non -traditional tree species used in the furniture industry in Masaka District, Central Uganda. *Uganda Journal of Agricultural Sciences, 12(1):* 57-66.

American Society for Testing and Materials 1975. Standard methods of evaluating the properties of wood base fiber and panel materials. ASTM D 1037-72. Philadelphia, Pa.

Beech, J. C. 2010. The thickness swelling of wood particleboard. Holzforschung 29(1)

Gatchell, C. J, B. G. Heebink, and F. V. Hefty 2017. Influence of component variables on properties of particleboard for exterior use. For. Prod. J. 16 (4)

Geimer, R. L, H. M. Montrey, and W. F. Lehmann 2014. Effects of layer characteristics on the properties of three - layer particle boards. For. Prod. J. 25 (3)

Howards, E. T. 1974. Slash pine root wood in flake board. For. Prod. J. 24 (6)

Hse, C.-Y. 2013. Characteristics of urea- formaldehyde resins as related to glue bond quality of southern pine particleboard. J. Jap. Wood Res. Soc. 20 (10)

Hse, C.-Y. 2013. Reaction pH of urea-formaldehyde resins as related to strength properties of southern pine particleboard. J. Jap. Wood Res. Soc. 20(10)

Kollmann, F. P, E. W. Kuenzi, and A. J. Stamm 1984. Principles of wood science and technology. Vol. II. Wood- based materials. Chap. 5. Springer-Verlag, New York, 703

Lehmann, W. F. 2015. The effects of moisture content, board density

Liiri, O. 2010. Investigations into long-term moistening of wood particle board and the effect of changes in moisture on its qualities. Pap. Puu 43

APPENDIX

QUESTIONNAIRE FOR WOOD CARVERS

PREAMBLE

The researcher is a Post – Graduate student of Akenten Appiah Menka University of Skill Training and Entrepreneurship Development. He is researching on the perception of the use of bonded sawdust as a substitute material for carving. This questionnaire is meant to seek opinion to help him successfully complete the programme which will lead to the award of Master of Technology Education in Wood science. Please your responses to these questionnaires will assist the study immensely. Information gathered from you will be used only for academic purpose and confidentiality is much assured. The researcher also pledges to conceal the identity of all respondents who voluntarily give the needed information as required by this questionnaire. Please you are at liberty to tick **(√)** in the appropriate box to express your view. You are not under any compulsion to respond to all the questionnaire items.

SECTION A: PERSONAL PARTICULARS

1. Please indicate your gender. *Please tick [√]*

   Male [ ] Female [ ]

2. What is your age category? *Please tick [√]*

Below 20 years	20 – 30 years	31- 40 years	41- 50 years	51- 60 years	Above 60 years

3. What is your highest academic qualification? *Please tick [√]*

Masters	
First Degree	

HND	
Technician certificate	
Other Please State……..	

4. How many years have you been working with your organization? *Please tick [√]*

Less than 5 years	5-10 years	11-15 years	16-20 years	Over 20 years

SECTION B: Fashioning sawdust into boards and blocks

ITEM	**Strongly Agree**	**Agree**	**Undecided**	**Disagree**	**Strongly Disagree**
Sawdust can be molded into different shapes and size					
Sawdust have no commercial value					
Sawdust can be obtained in large quantities					
Sawdust board is odourless					
Sawdust when turned into boards may have excellent surface finish					
Sawdust board is environmentally friendly					

SECTION C: The factors that influence timber species selection for carving works.

Please tick [√] to indicate your level of agreement or disagreement in the following items in relation to factors that influence timber species selection for carving works.

Factors that influence Species selection	**SA**	**A**	**N**	**D**	**SD**
Wood as building material will be used because of its durability and other mechanical and physical properties					
Appearance					
Quality					
Processability					
Affordability					
Area of usage					
Informed decision					
Type of product					
Expert advice					
Suitability					
Sustainability					
Availability					
Price					
Thickness sizes					

SECTION D: Using sawdust board or block as carving materials

ITEM	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Carving an artifact from sawdust particle board requires a sharpened edge tools					
Sawdust board/block is light in weight					
Sawdust board/block have good workability					
Carving an artifact from sawdust particle board is easy to work with					
Carvings from sawdust particle board are beautiful					
Carvings from sawdust particle board do not produce waste					

SECTION E: The quality of carved pieces from sawdust blocks/board

ITEM	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	TOTAL	RATING
Sawdust particle board size and							

shape has influence on the strength							
Sawdust board has a very good bonding property							
Sawdust boards has its major constituents as fibers and fiber bundles							
Carvings from sawdust particle board are durable							
Carvings from sawdust particle board will not rot, crack, warp							
Carvings from sawdust particle board are 100% termite and water proof							