COMPARATIVE ANALYSIS OF PARTICLE BOARDS MADE FROM AGRICULTURAL WASTES USING GUM ARABIC AS BINDING RESIN

BY

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MATRIC No. 2006/24077EA

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FEBRUARY, 2012.

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG.) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHONOLGY, MINNA, NIGER STATE

FEBRUARY, 2012.

DECLARATION

I hereby declare that this project work is a record of a research work that was under taken and written by me. It has not been presented before for any degree or diploma or certificate before at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in text.

31/03/2012

SUGH, USHA

DATE

CERTIFICATION

This is to certify that the project entitled "Comparative Analysis of particle boards made from Agricultural waste using Gum Arabic as binder" by Sugh, Usha meets the regulations governing the award of the degree of Bachelor of Engineering (B.ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

______________________ 27th Feb. 2012

Engr. Mohammed A. Sadeeq — Date

Supervisor

______________________ 27/02/2012

Engr.Dr. P.A.Idah — Date

H.O.D., Agricultural and Bioresources Engineering

______________________ 22-02-2012

External Examiner — Date

DEDICATION

This project work is dedicated to the almighty GOD in heaven for been my inheritance, for perfecting his strength in my weaknesses, for his abiding presence that brings glory and beauty to my life and above all for the gift of life.

ACKNOWLEDGEMENTS

It is a privilege to have been a student of Agricultural and Bioresources Engineering stream in Federal University of Technology Minna.

My profound gratitude goes to the almighty GOD in heaven for been my inheritance, for perfecting his strength in my weaknesses, for his abiding presence that brings beauty to my life and above all for the gift of life.

I want to appreciate my supervisor Engr.M.A. Sadeeq for creating time to carefully supervise my work despite his tight schedule may God bless you in all your endeavors. My appreciation goes to all the lecturers and staff of the Department of Agricultural and Bioresourecs Engineering, especially Engr.Dr.I.E. Ahaneku, Mrs. Bosede Orhevba, Mr.Kehinde and Mr.Aliyu for their various contributions to me throughout my time of study.

Ability without opportunity is of no use; my sincere appreciation goes to my parents Mr. Joseph Akaayar Sugh and Mrs. Mbabeen Sugh for their parental decision to give me qualitative education and the required encouragement needed throughout my time of study. Mama you are a special and irreplaceable woman in the women folk, you are a daughter of Zion in Israel.

I want to thank my uncle Mr. J.E.T. Sugh and his wife Mrs. Anna Sugh for teaching me the fundamental principles of humility, respect and integrity, and for giving me qualitative elementary education which has made a difference in my life.

My heart felt appreciation goes to Rev. Nathaniel ,Terna Ayegh (N.T.A.) and his wife Mrs.Dorcas Ayegh for exhibiting the maximum level of acceptable behaviours and for been a

medium of propagation in meeting my needs throughout my time of study. May the almighty GOD strengthen and up lift you people in your ministry.

I remain grateful to my brother Mr. Sooter Sugh, and my sisters miss Nadoo and Miss Doose Sugh for coexisting with me throughout my time of study. I also want to appreciate my cousins Mr. Fanen Sugh, Miss seember Sugh, Mr. Shim saaor, Mr.Ayegh Titus and Mr.Aver Doo. I want to appreciate my friends Osunnda Manaseh, Goke Popoola, Otuweh Saint, Aruna Benson and Nguzhul Micheal.

ABSTRACT

This study was aimed at producing particle boards from agricultural wastes (Sawdust, Sugarcane bagasse, Melon shell and Rice husk) using Gum Arabic as a binding resin in place of the synthetic resin normally used. These were achieved by forming a composition of the materials used in the ratio 1:1, 1:1:2 and 1:1:1:1 respectively and forming them into particle boards using mat-form method. The formed boards were replicated three times and subjected to compressive test, moisture content test and porosity test. The results obtained from this study work was subjected to a statistical analysis using SPSS 17.0 (statistical package for social science) and it showed that the properties of the particle boards depend on the particle sizes of the waste material, quality of the resin binder and the method of forming. Also the mixture of sawdust, sugarcane bagasse rice husk and melon shell showed a great strength and low moisture content. The densities of the formed boards are A= 571.6Kg/m^3, B = 680.31Kg/m^3, C = 654.9Kg/m^3, D = 854.3Kg/m^3, AB = 663.0Kg/m^3 AC = 648.6Kg/m^3 AD =745.3Kg/m^3 BC = 696.3Kg/m^3 CD = 875.7Kg/m^3 ABC = 751.8Kg/m^3 BCD = 908.3Kg/m^3 ACD = 860.2Kg/m^3 ABCD = 916.6Kg/m^3 showing low density board, with a compaction force of 500N and pressure 3333.3N/m. The resulting particle boards are of high quality and with good size requirement. A medium scale production plant is hereby recommended for development.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

A particleboard is defined as a panel product manufactured from lignocellulosic materials, primarily in the form of discrete particles, combined with a synthetic resin or other suitable binder and bonded together under heat and pressure. The primary difference between particle board and other reconstituted wood products, such as wafer board, oriented strand board, medium density fibre board, and hard board, is the material or particles used in its production. (J.G. Haygreen and J.L. Boyer, 1989). Particleboard was invented in the late 1940s by German inventor, Max Himmelheber, as a replacement for plywood. Using waste materials such as planer shavings and sawdust bound together by phenolic resin, the first commercial piece was produced in Bremen, Germany during the Second World War. As time went on, other manufacturers started to produce them from similar materials, but using slightly different resins. Manufacturers discovered that they could achieve better strength, appearance and resin economy by using more uniformed, manufactured chips. These finer more uniformed layers made by processing solid birch, beech, alder, pine and spruce, were placed on the outsides of the board, and then the board's central section was composed of coarser, cheaper chips or flakes. Boards produced this way are called three-layered particleboard ("http://en.Wikipedia.org/wiki particle_board" 14th February, 2011).

Conventional particleboard is manufactured by mixing wood particles or flakes together with a resin and forming the mix into a sheet. The raw material to be used for the particles is fed into a disc chipper with between four and sixteen radially arranged blades. The particles are first dried, after which any oversized or undersized particles are screened out.

Resin, in liquid form, is then sprayed through nozzles onto the particles. There are several types of resins that are commonly used. Amino, formaldehyde based resins are the best performing when considering cost and ease of use. Urea Melamine resins are used to offer water resistance with increased melamine offering enhanced resistance. Phenol formaldehyde is typically used where the panel is used in external applications due to the increased water resistance offered by phenolic resins and also the colour of the resin resulting in a darker panel. Melamine Urea phenolic formaldehyde resins exist as a compromise. To enhance the panel properties even further the use of resorcinol resins typically mixed with phenolic resins are used, but this is usually used with plywood for marine applications and a rare occasion in panel production.

Panel production involves various other chemicals — including wax, dyes, wetting agents, release agents — to make the final product water resistant, fireproof, insect proof, or to give it some other quality.

Once the resin has been mixed with the particles, the liquid mixture is made into a sheet. A weighing device notes the weight of flakes, and they are distributed into position by rotating rakes. In graded-density particleboard, the flakes are spread by an air jet that throws finer particles further than coarse ones. Two such jets, reversed, allow the particles to build up from fine to coarse and back to fine.

The sheets formed are then cold-compressed to reduce their thickness and make them easier to transport. Later, they are compressed again, under pressures between two and three megapascals and temperatures between 140 °C and 220 °C. This process sets and hardens the glue. All aspects of this entire process must be carefully controlled to ensure the correct size, density and consistency of the board. The boards are then cooled, trimmed and sanded. They can then be sold as raw board or surface improved through the addition of a wood veneer or laminate surface.

1.2 Statement of the Problem

The growing shortage of wood has led researchers to finding ways of developing suitable alternatives for the production of particleboards. The lacuna in agricultural waste management constitutes severe environmental threats. To this end, agricultural by- products like rice husk, sugarcane bagasse, melon shell and sawdust can be re-used in the production of particle boards.

1.3 Objectives

This study has the following objectives:

1. To examine the possibilities of substituting synthetic resin adhesive (urea formaldehyde) with gum Arabic as a binding resin in the production of particle board.
2. To effectively manage agricultural waste thereby reducing the increasing demands on plywood.
3. To convert agricultural wastes produce such as melon shell, rice husk, sugarcane bagasse and sawdust to job creating opportunities through my knowledge of entrepreneurship
4. To analytically compare some engineering properties (physical and mechanical) of the particle boards produced, with a view of choosing which one of them is good.

1.4 Justification of the Study

Particle board is a three-layered board with fine particles on the top and bottom surfaces and layer wood flakes in the middle. It has been used widely for constructional and industrial purposes in recent times. This is due to the fact that it is lighter than the conventional wood yet it retains a great deal of strength and stability. It is ideal for use in applications where a lighter panel is important. Particle board allows you to achieve fast, cost effective building results whilst maintaining our precious rainforest and wilderness.

However, this project focuses on recycling of agricultural bye- products (melon shell, rice husk, sugarcane bagasse and sawdust) to meet the demand created by decrease in available supplies of solid wood and wood-base materials in the production of particle board.

1.5 Scope of Study

The particle boards from this project is produced from agricultural- bye products (rice husk, melon shell, sugarcane bagasse and sawdust) using gum arabic as a natural binding resin, instead of the synthetic resin (urea formaldehyde).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Particle board Production from Agricultural Wastes using Gum Arabic

Particle board was invented in the 1940s as a cheaper alternative to natural wood. It is manufactured from waste products of natural fibrous materials and wood particles such as saw-dust, chips and shavings, held together by synthetic resins which act as adhesives. The properties of the particle board formed depend physical and chemical properties of the materials used, the type and amount of the adhesive used, the moulding method employed and the amount of pressure applied in the its manufacture. Other factors may also include the amount, nature and softness of the cellulose content present in the cell walls of the fibrous materials used. Characteristics such as the nail and screw holding properties of the board are determined by the quality of the resin that glues the boards particles together. (http://en.Wikipedia.org/wiki particle_board.html 6th April, 2011)

2.2 Recent Classifications of Particle boards are based on Three Major Classes.

The first is according to the density grades under which the weight per cubic centimeter of the board is put into consideration. Under this class, we have the low density particle board also referred to as the insulating type with a density of 350kg/m^3 – 1400kg/m^3, the medium density or decorating type with a density of 1500kg/m^3 - 1700kg/m^3 and the high density or hard board type mainly used for heavy construction with a 1800kg/m^3 - 2100kg/m^3 density. These different densities are achieved by the applied pressure during the manufacturing process.

The second classification is based on the thickness or size under which exist the standard particle board (1.2m x 2.4m x 0.025m), common panel size (ranging from 0.0125m –

0,025m) and the three-layer particle board which has the finer layer placed on the outside and the coarse layer placed in the central section.

The third classification is based on the method of production of the board. There are basically two methods of producing the particle board namely the extrusion method and the mat-formed method.

The extrusion method is a technologically advanced method that passes the raw chips through series of processes, sprays adhesives through jets and compresses the particles under conditioned temperatures and pressures. The final hardened board of correct size, density and constituents is then cooled, trimmed and sanded. Finally, finishing touches such as paper lamination and covering with wood veneer are done.

The mat-formed method is a simpler method than the extrusion method. In this method, the particles are first dried and grinded into a uniform homogenous form. These particles are then mixed with the adhesive and spread into sheets or moulds, after which they are pressed together to achieve the desired density. The pressed boards are allowed to cure and then trimmed to standard sizes using multiple saws and precision sanding is applied on both sides to attain the required thickness. (Adegbemi, 2010).

2.3 Adhesives

An adhesive is a compound that bonds particles together. Adhesives may be produced from either synthetic or natural sources. Adhesives are advantageous for joining thin or dissimilar materials and minimizing weight although unlike most other joining agents, they take time to cure. Before 1930 the basic adhesives were based on animal glues, casein, clays, mastics, pitches, asphalts bitumen's, starch, blood and resin. (Julian R. Panek and John Philip Cook, 1999)

Adhesives used in the production of particleboard should be flexible and soft to the dynamic effects of swelling and shrinkage, yet impart the required strength. It must also withstand to increase the rigours of particleboard manufacturing with sufficient flow to increase particle coverage.

This project work uses Gum Arabic as the adhesive for binding the particleboard components together. This is due to its being affordable, highly glossy, and odorless and also its good ink retention. Its disadvantage which is vulnerability to insect attacks and how it can be handled, are beyond the scope of this project.

2.3.1 Types of Adhesives

i. Natural Adhesives:

Natural adhesives are made from organic sources such as vegetable matter, starch, natural resins or from animals. Also known as bio adhesives, these adhesives are used in bookbinding, wood joining, wallpaper pasting and more.

ii. Synthetic Adhesives:

These are resins made by artificial or chemical means. A combination of urea and formaldehyde, urea-formaldehyde, is the mostly used in interiors as it is cheaper and easier to use than melanin-formaldehyde. Phenol-formaldehyde is used where the board is subjected to extreme heat or humidity or for exterior applications. (Anbu*eta.l*, 2006)

2.3.2 Characteristics of Adhesives

An adhesive can be used if it has the following attributes:

1. Low moisture content.

2. Resistance to creep at high temperatures.

3. Ease of application.

4. Dehydration of binding area.

5. Flexibility of application.

2.4 Gum Arabic

Gum Arabic is a natural gum exuded by various species of acacia. The main source of commercial gum Arabic is acacia Senegal L. wild; also called acacia verek. The trees grow mainly in the sub-Sahara or Sahel zone of Africa and also in Australia, India and America. (Alan Imeson, 1997).The main producing and exporting countries in the 'gum belt' include Senegal, Mali, Mauritania, Niger Chad and Sudan.

2.4.1 Manufacturing of Gum Arabic

i. Collection and grading

Gum Arabic is exuded from acacia Senegal or 'hashab' trees in form of large (5cm diameter) striated nodules or tears. Mature trees, 4.5m high and 5-25 years old, are tapped by making incisions in the branches and stripping away the bark to accelerate exudation. The gum dries into rough spheres, which are manually collected and taken to the markets. Collection takes place at intervals during the dry season from November to May and two main harvests are taken in December and April. (Thevent, 1988).

ii. Properties and Structure of Gum Arabic

Gum arabic is classed in a group of substances called *arabinogalactan proteins*. In more descriptive terms, it is essentially a polysaccharide, comprised mostly of galactose, arabinose, rhamnose, and glucoronic acid. It also contains a small amount of protein.Gum arabic readily dissolves in water to form highly concentrated solutions that are of relatively low viscosity, which is as a result of the gum's highly branched very compact structure. Gum is quite heterogeneous in nature with at least three discreet components:

The first, comprising about 90% of the gum, has a molecular weight of about 250,000 and contains a negligible amount of amino acids. It is suggested by analysts that the structure of this component is globular and highly branched.

The second component, making up about 10% of the total, has a molecular weight of 1,500,000, and contains about 10% protein. It is thought to have a structure consisting of five globular lobes of carbohydrate of molecular weight of about 250,000 each, which are attached to a common polypeptide chain. The predominant amino acids in this component are hydroxyproline and serine.

Comprising less than 1% of the total gum, the third component contains 20 – 50% protein located deep in the center of the molecule. It is highly compact with a molecular weight of 200,000. The predominant amino acids in this component are aspartic, serine, leucine, and glycine. (A. Bacic, et al, "Structural Classes of Arabinogalactin - Proteins").

(http://pacifier.com/~kthayer/html/Gumarabic.html,24th March, 2011)

2.5 Rice

Rice is the seed of the monocot plants *Oryza sativa* or *Oryzaglaberrima*. As a cereal grain, it is the most important staple food for a large part of the world's human population, especially in East and South Asia, the Middle East, Latin America, and the West Indies. It is the grain with the second-highest worldwide production, aftermaize (corn).

Rice is the only cereal that is largely consumed whole by man as harvested (of course, after dehulling and polishing) and is usually simply boiled n for direct consumption. Over one-half of the world's population subsists wholly or partially on rice. It is the principal food for the far east where meat, fish, fowl, vegetables, pusles and condiments are considered only as garnishes for the main dish of rice. In some countries of orient, the per capital rice consumption is estimated at 45-90 kg annually as compared to only about 3.6 kg in the united states. (Kochar S.L., 1998).

Rice is normally grown as an annual plant, although in tropical areas it can survive as a perennial and can produce a ration crop for up to 30 years. The rice plant can grow to 1 – 1.8 m (3.3 – 5.9 ft) tall, occasionally more depending on the variety and soil fertility. It has long, slender leaves 50 – 100 cm (20 – 39 in) long and 2 – 2.5 cm (0.79 – 0.98 in) broad. The small wind-pollinated flowers are produced in a branched arching to pendulous inflorescence 30–50 cm (12 – 20 in) /long. The edible seed is a grain (caryopsis) 5 – 12 mm (0.20 – 0.47 in) long and 2 – 3 mm (0.079 – 0.12 in) thick.

Rice cultivation is well-suited to countries and regions with low labor costs and high rainfall, as it is labor-intensive to cultivate and requires ample water. Rice can be grown practically anywhere, even on a steep hill or mountain. Although its parent species are native to South Asia and certain parts of Africa, centuries of trade and exportation have made it commonplace in many cultures worldwide. (Kochar S. L., 1998).

The traditional method for cultivating rice is flooding the fields while, or after, setting the young seedlings. This simple method requires sound planning and servicing of the water damming and channeling, but reduces the growth of less robust weed and pest plants that have no submerged growth state, and deters vermin. While flooding is not mandatory for the cultivation of rice, all other methods of irrigation require higher effort in weed and pest control during growth periods and a different approach for fertilizing the soil.

Unmilled rice, known as paddy, is usually harvested when the grains have a moisture content of around 25 percent. In most Asian countries, where rice is almost entirely the product of smallholder agriculture, harvesting is carried out manually, although there is a growing interest in mechanical harvesting. Harvesting can be carried out by the farmers themselves, but is also frequently done by seasonal labour groups. Harvesting is followed by threshing, either immediately or within a day or two. Again, much threshing is still carried out by hand but there is an increasing use of mechanical threshers. Subsequently, paddy needs to be dried to bring down the moisture content to no more than 20 percent for milling. A familiar sight in several Asian countries is paddy laid out to dry along roads. However, in most countries the bulk of drying of marketed paddy takes place in mills, with village-level drying being used for paddy to be consumed by farm families. Mills either sundry can use mechanical driers or both. Drying has to be carried out quickly to avoid the formation of moulds. Mills range from simple hullers, with a throughput of a couple of tons a day that simply remove the outer husk to enormous operations that can process 4,000 tons a day and produce highly polished rice. A good mill can achieve a paddy-to-rice conversion rate of up to 72 percent but smaller, inefficient mills often struggle to achieve 60 percent. These smaller mills often do not buy paddy and sell rice but only service farmers who want to mill their paddy for their own consumption.

2.5.1 Rice Husk

The reasons behind the use of rice husk in the construction industry are its high availability, low bulk density, toughness, abrasive in nature, resistance to weathering and unique composition. Its main components are silica, cellulose and lignin.

Rice husks contain a high level of silica in amorphous and crystalline forms. The presence of amorphous silica determines the pozzolanic effects of rice husks. This is exhibited in the cementitious properties that increase the rate at which the material gains strength. The external surface of the husk contains high levels of amorphous silica which decreases inwards and is practically non-existent within the husk. ("http//en.wikipedia.org/wiki Rice_production.html" 9th April, 2011).

2.6 Sugarcane

Sugarcane refers to any of 6 to 37 species (depending on which taxonomic system is used) of tall perennialgrasses of the genus *Saccharum* (family Poaceae, tribe Andropogoneae). Native to warm temperate to tropical regions of Asia, they have stout, jointed, fibrous stalks that are rich in sugar. Sugarcane is essentially a crop of the tropics and sub tropics of the world between 30 north and south of the equator. It grows on almost all classes of the soil, ranging from sandy soils to heavy loams but clay loams with good drainage are suited. All sugar cane species interbreed, and the major commercial cultivars are complex hybrids. (Kochar S.L, 1998)

Brazil is the biggest grower of sugarcane, which goes for sugar and ethanol for gasoline-ethanol blends (gasohol) for transportation fuel. In India, sugarcane is sold as jaggery, and also refined into sugar, primarily for consumption in tea and sweets, and for the production of alcoholic beverages.

Sugarcane requires a considerable amount of water during the period of active growth for maximum yield. About (200-225cm of rainfall annually or adequate irrigation), an average temperature of 26, a dry sunny and frost free ripening period. High temperatures above 50 and cold weather below 16 arrests the growth of the cane. It is a heavy feeder and, and therefore, adequate manuring is vital for the sustained for a sustained high yield. The crop is very sensitive to sunlight; abundant light promoting tillering. (Kochar S.L, 1998)

Although sugarcanes produce seeds, modern stem cutting has become the most common reproduction method. Each cutting must contain at least one bud and the cuttings are sometimes hand-planted. In more technologically advanced countries like the United States and Australia, billet planting is common. Billets harvested from a mechanical harvester are planted by a machine which opens and recloses the ground. Once planted, a stand can be harvested several times; after each harvest, the cane sends up new stalks, called ratoons. Successive harvests give decreasing yields, eventually justifying replanting. Two to ten harvests may be possible between planting.

2.6.1 Sugarcane Bagasse

Sugarcane bagasse is a fibrous matter left after sugarcane stalks are crushed to extract their juice.In a sugarcane factory, for every 10 tonnes of sugarcane crushed, 3 tonnes of wet bagasse is gotten. The quantity of production in each country or region would depend on the amount of sugarcane it produces.A typical chemical analysis shows that it contains:

Cellulose 45 – 55%

Hemicelluloses 20 – 25%

Lignin 18 – 24%

Ash 1 – 4%

Waxes < 1%

Bagasse is mainly used as biofuel and in paper and pulp production. Only recently has it started being considered as material in particleboard production.

2.7 Melon

Melon, cucmeropsisedulis is a vegetable product. Melon have long been discovered to have originated from Asia and was firstly transported in to Italy and extended to France before the sixteenth century. Melon are some how related to the family of summer squash which includes as fruit vegetable plant which is also intercropped with maize. There are many varieties of melon which includes water melon (citrus vulguris), rock melon, honey dew and prince melon. In Nigeria, many types of melon are grown some are grown for their succulent fruit such as water melon while some are grown for the purpose of seeds. Melons are of various uses to faers and consumers, melon can be used for vegetable oil production, for soap production and for the production of melon cake. Melon is usually grown in the soil which is very rich in organic matter (fertile soil) and can be planted at the beginning of raining season usually between March, April and June. Akobundu (1987)

2.8 Sawdust

Sawdust and shavings or chips (residues left in saw and plaining mills), once mostly used for boiler fuel, are now being increasingly used for many industries. Sawdust finds its use as an absorbent for floor coverings (particularly in butcher shops, machine shops, garages, factories and warehouse); as stable and kennel beddings; in leather manufacture; for cleaning, drying and polishing metals, as a packing medium for great number of commodities; in sawdust mulches(or as a soil conditioner) and as an insulating material.(Kochar S.L,1998).

Sawdust is an important component of a number of composition flooring, clay products, board products, floor sweeping compounds, moulded articles and plastics, concrete products and artificial stones and abrasives. A host of chemicals are obtained from sawdust and shavings by destructive and steam distillation. Sawdust mixed with wood chip wood from sawmills, is still widely employed for domestic as well as industrial heating. The principal use of shavings is for fuel either as it is or in the form of wood briquettes, but together with sawdust they may be used for a good number of uses mentioned above. Large chips may be included in 'pulping charges'. (Kochar S.L, 1998).

2.9 Manufacturing Procedure of Particleboards

The initial process in producing a particleboard involves sourcing for materials to be used and processing them into chips and splits. The chips are then sieved into uniform sizes, dried to achieve uniform moisture content and then blended with adhesives. The mixture of resin and wood particles is compressed to the desired density, formed into mat, and cured under heat and pressure. There are two major methods for curing the particleboard;

i. Extrusion method. (highly technical and expensive)
ii. Mat-formed method. (simple and less expensive)

i. Extrusion Method.

In the extrusion method, the particles are fed into a disc chipper with radially arranged blades and resin is sprayed into the particles through nozzles. The flakes are then spread by air jets which separate the finer ones from the coarse ones and allow them to build up from fine to coarse and then back to fine, thereby making sure the board is strongest at the middle. The mixture is made into sheets by an oil heated plate serving as a weighing device that compresses the spread of the mixed particle on a continuous sheet of moving belt into sized thickness and width. This process takes place at pressure of 2 – 3 megapascal and a temperature between 140°C – 220°C and it sets and hardens the glue. After pressing, the boards generally are cooled prior to stacking. The particleboard panels then are sanded and trimmed to final dimensions, any other finishing operations (including lamination or veneerapplication) are done, and the finished product is packaged for shipment.

ii. Mat-Formed Method.

This is a simpler method than the extrusion method. In this method, the particles are first dried and grinded into a uniform homogenous form. These particles are then mixed with the adhesive and spread into sheets or moulds, after which they are pressed together to achieve the desired density. The pressed boards are allowed to cure and then trimmed to standard sizes using multiple saws and precision sanding is applied on both sides to attain the required thickness.

2.9.1 Properties of Particle Board.

The properties of particleboards greatly depend on the nature and structure of the raw material used, amount of adhesive, and the method of forming. The following are properties that determine the quality of the board;

i. Tensile Strength

This is the resistance of a body to tensile forces that tend to pull it apart. It determines the relationship between stress and strain in a material by the means of tensile test (Shukar, 1977).

ii. Hardness

Hardness is ability of a solid material to resist surface deformation or abrasion. It can be determined by material's capacity for bending through a definite angle one or more times without fracture. Hardness should not be confused with strength or toughness of a material.

iii. Abrasion Test

This measure the amount of scratch a material can withstand. It is done by scratching the smooth surface of the material to be tested. (Gladius, 1977)

iv. Plastic Limit

This determines the moisture content at which the board will become too dry to be in a plastic condition.

v. Nailing Test

This property determines the ability of the board to withstand nailing or stretching without the splitting of disintegration of the adhesive used. In other words, it is done to ascertain the material's bonding strength. A particleboard should have a minimum holding force of 178N

vi. Moisture Content

This is the weight of water contained in a given sample of a particle, expressed in percentage. It is mathematically defined as the ratio of weight of wet sample minus weight of dry sample divided by weight of dry sample minus weight of container all multiplied by hundred.

vii. Density

Density is the measure of strength of the material, depending on the pressure applied per unit volume. It is expresses in kilogram per cubic meter or in the ratio of a mass of a body to its volume. The recommended densities for particleboards are $350kg/m^3$ – $1400kg/m^3$ for low density and $1600kg/m^3$ – $2100kg/m^3$ for high density boards.

viii. Fire Resistance

This is the ability of the board to withstand the heat of fire for some time, before burning begins. This varies widely between materials and depends largely on their composition. Additives that are known to increase fire resistance can be added in the mixing process.

ix. Compressive Strength

This is a materials ability to resist compressive force before it collapses. It is the ratio of the failure under compressive load to the multiple of the length of the breadth of the material and its thickness measured in kg/cm^2.

x. Static Bending

This is the ability of a material to withstand static load. It results from pressure from either a dead load or variable load. This is an important property as it helps ascertain the maximum allowable load on materials. (Gladius, 1977)

2.9.2 Finishing Process of Particleboard

Because particleboards are very versatile and applicable in quite a number of uses, there are numerous finishing procedures for them. The following are some of the finishing processes involved:

i. Sanding

The quality of most particleboards is such that sanding is not required. But sawed edges and machine scratches can be dressed up by sanding procedures.

ii. Machining

Operations such as shaping, routing and planning and others commonly applied on other wood products can be achieved with machining. Results are best when tools are kept clean.

iii. Laminating

This is done to help the board resist dampness and change in colour due to attack by fungi. The board is laminated with paper or veneer, giving it an aesthetic look and also eliminating the need for painting.

iv. Sawing

This can be done with the use of either a hand saw or a power saw. For a better result and higher quality, it is better to use the power saw that is carbide tipped.

v. Screwing and Bolting

There are specially designed screws and nails for particleboards, as ordinary ones would lose hold over time. Holes smaller than the diameters of the screws should be drilled to accommodate their shake.

vi. Fastening

Nails, staples, bolts, adhesives, rivets and other common fasteners can be used to hold particleboards together.

vii. Painting

Much sophistication is not required to apply paint on a particleboard. Normal tools such as brushes, sprayers and rollers can be used. In the case of particleboards used for interiors, sealers are not necessary but if they must be used, it is advised that they should be rubber or vinyl based white sealers.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Materials/Equipment

The materials used for the production and characterization of the particle boards from agricultural by- products are given in Table 3 and 4. This is to give the materials used, source of the materials, botanical names and comments.

Table 3.1 Materials used for the Project

Materials	Sources	Botanical names	Comments
Sugarcane bagasse	National cereal National Cereal Research Institute Badeggi, Bida	*SaccharumOfficinarum*	Dried and crushed into smaller particles
Rice husk	National cereal research institute badegai, bida	*Oryza sativa*	Dried and crushed into smaller particles
Melon Shell	Gwari Market Minna	*CucumeropsisMannii*	Dried and crushed into smaller particles
Saw Dust	Timber Market Minna		Dried and crushed into particles
Gum Arabic	Engineer Kure Ultra Modern Market Minna	*ArabinoGelactan*	Shredded, crushed, sieved and dissolved in hot water
Water	Tap water		Washing items

Table 3.2 Equipment Used for the Project

Material	Sources	Research Code
Galvanized square shape mould with steel pallet cover. mould dimension 150mm×100mm×20mm	Engineering central workshop	
Electronic weighing balance	Saunter England	Digital calibrated in (g)
Graduated measuring cylinder	Made in England	BS 410/1986
British standard sieve	Made in England	BS 410/1986
Mortal and Pestel	Made in Nigeria	Wooden frame
Stop clock	Made in Nigeria	
Grinding machine	Made in Nigeria	
Oven	Made in England	BS 410/1988
Plastic basin	Made in Nigeria	
Electric kettle	Made in Nigeria	
Rammer	Made in England	BS410/1986

3.2 Preparation of the Waste Materials (Melon Shell, Sugarcane Bagasse, Rice Husk and Saw Dust) using Gum Arabic as a binder

The waste samples used in the production of the particle boards were processed in order to obtain uniformity in size of the particles before been compressed into the various boards. The waste samples were dried daily under the sun to reduce the moisture content. The dried waste samples were broken into smaller particles (flakes) using a grinding machine. The grinded particles were again sun dried for several days to reduce the moisture content. The particles were sieved using the British standard sieve to achieve uniformity in the particle sizes.

Plate 3.1 Sawdust Particles

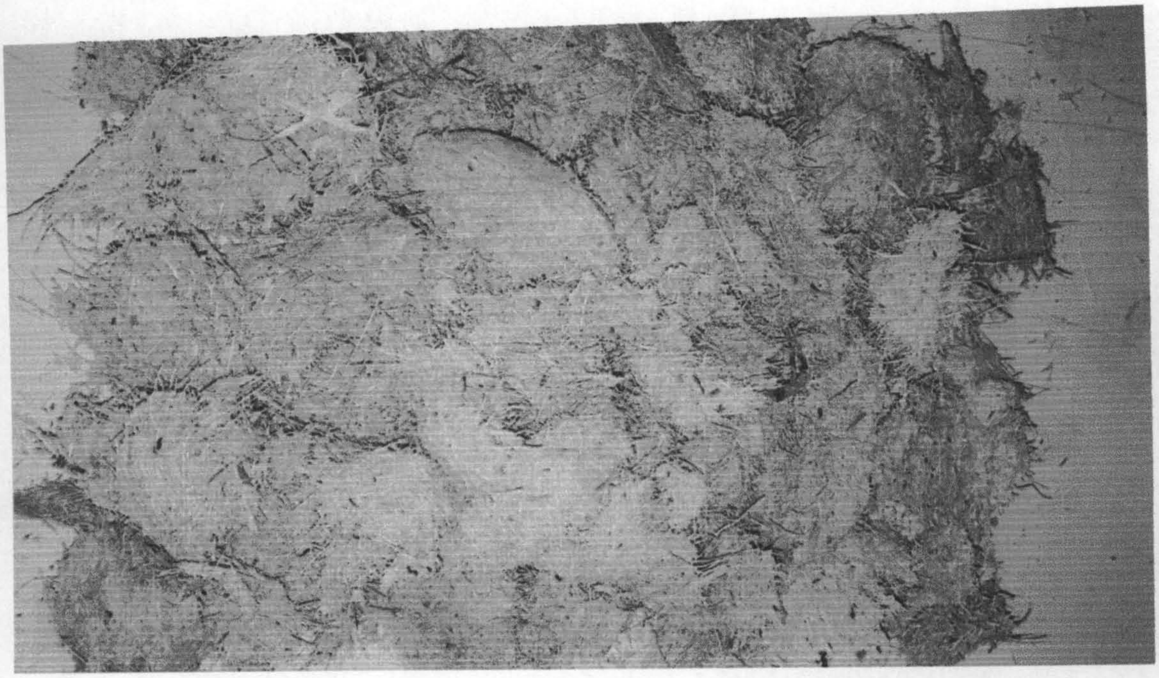

Plate 3.2 Sugarcane Bagasse

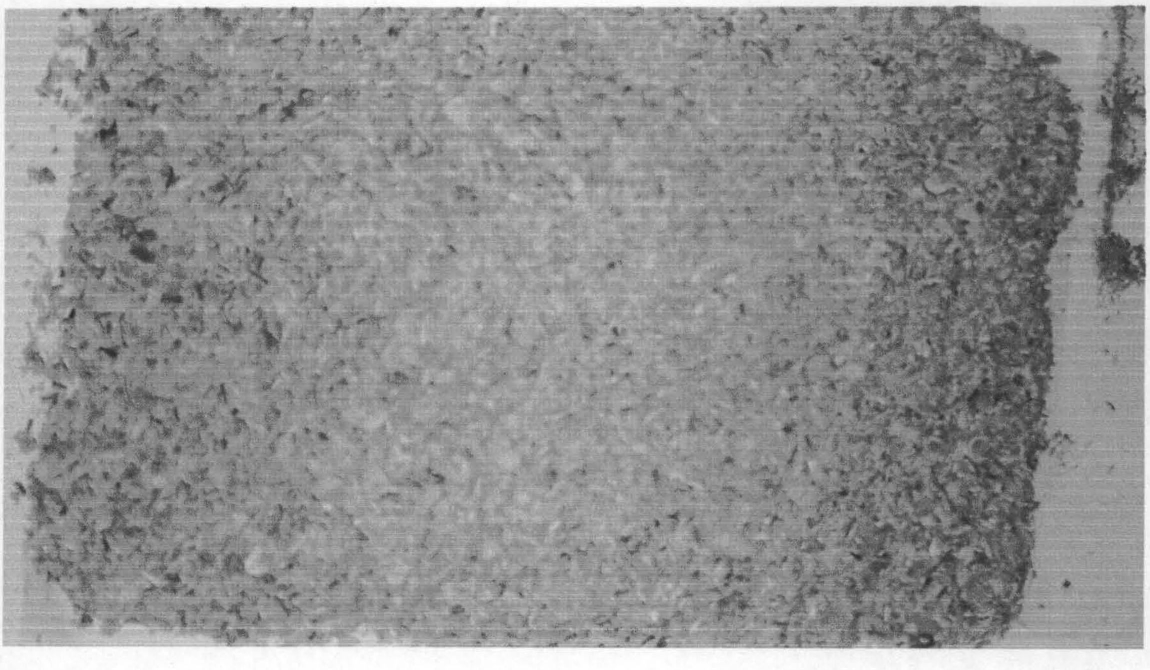

Plate 3.3 Melon Shell

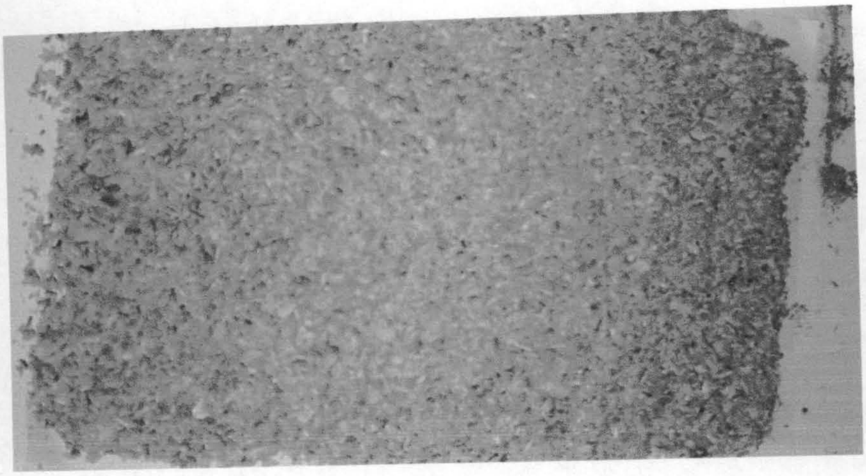

Plate 3.4 Rice Husk

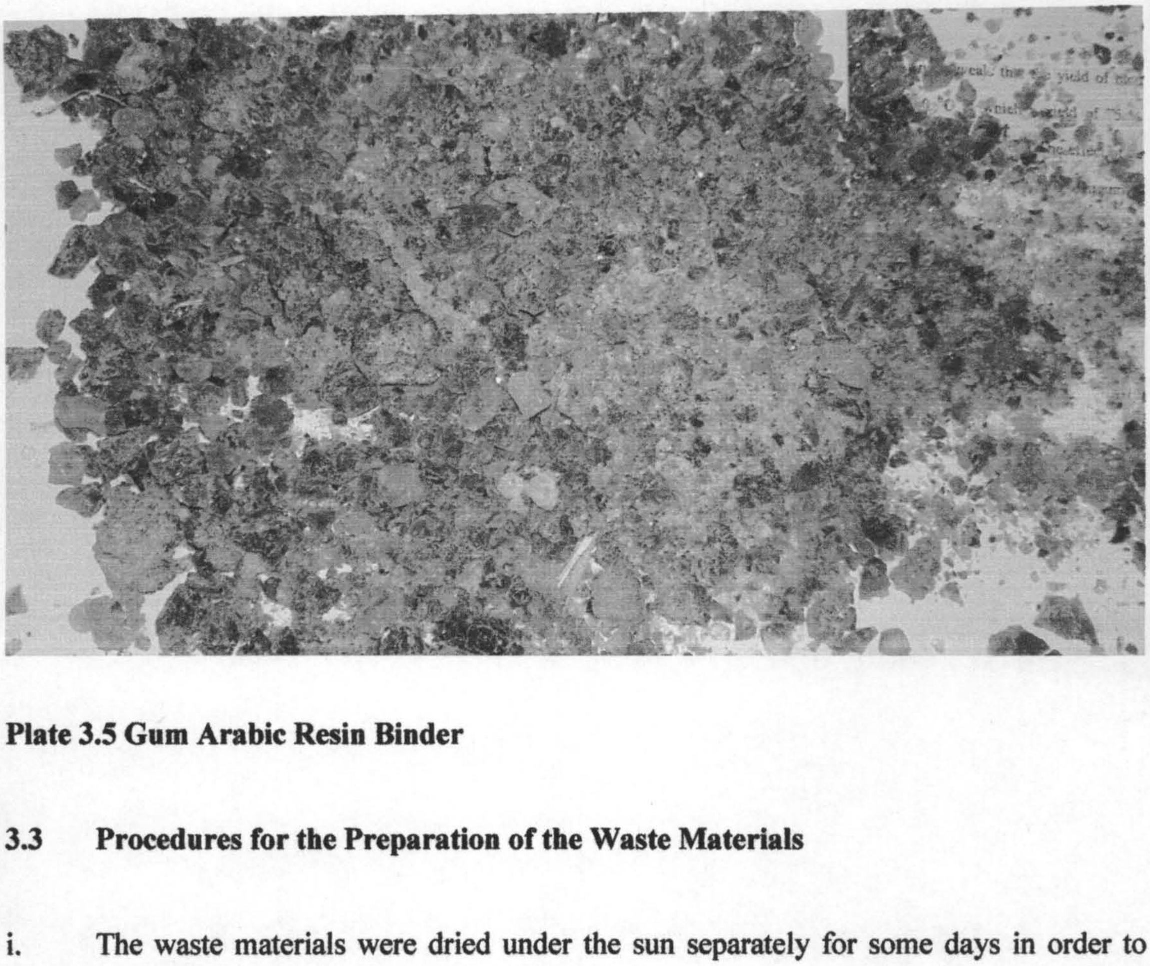

Plate 3.5 Gum Arabic Resin Binder

3.3 Procedures for the Preparation of the Waste Materials

i. The waste materials were dried under the sun separately for some days in order to enhance grinding or milling.

ii. The waste materials were reduced into smaller particle sizes (chips and flakes) using a grinding machine.

iii. The particles were sieved using the British standard to achieve uniformity in the particle sizes.

iv. A moisture content test was conducted in the laboratory to keep the particles below or within the 5% M.c after sun drying.

v. The solidified gum Arabic was crushed into smaller and sieved using the British standard sieve in order to remove foreign materials.

vi. About 50g of the sieved gum Arabic was dissolved in 0.5 litre of hot water at temperature 100^0C for 30 minutes. It was then stirred until a stable viscous mixture was obtained.

vii. The wastes samples (saw dust, sugarcane bagasse, melon shells, and rice husk) were weighed using an electronic weighing balance. The weighed samples were labeled (A: Saw dust, B: Sugarcane bagasse, C: Melon shells and D: Rice husk) respectively.

viii. The dissolved gum Arabic gum Arabic was mixed with the various waste samples based on the composite mixtures as shown in the appendices.

ix. The galvanized steel moulds were greased with oil to reduce frictional resistance created during the forming process.

x. Separate samples of "A B, A C, A D, B C, B D, C D of the waste samples were mixed in a ratio of 1:1 from the samples "A, B, C and D" above.

xi. Separate samples of "A B C, B C D, A C D, A, B and D" of the waste were mixed in a ratio of 1: 1:2 from the samples of "A, B, C and D above.

xii. A separate sample of "A B C and D" of the waste were mixed in a ratio of 1:1:1:1 from the samples of "A, B, C, and D above.

3.4 The Manufacturing Process of the Particle Boards

The samples of (A: sawdust, B: sugarcane bagasse, C: melon shells and C: Rice husk) were sieved using a British standard sieve of diameter 1.8mm in order to achieve uniformity in the particle sizes. The sieved particles were poured into different plastic basins and the liquid gum Arabic in a hot condition was added to the various waste samples and mixed thoroughly for about 5 minutes to form thick mixtures called "stuck". The mixtures were poured into the greased galvanized steel moulds of dimension 150mm x100mm x20mm and labeled A, B, C and D respectively for easy identification. The mixtures were forced spread using a standard rammer to achieve uniform compaction. The mixtures in the galvanized steel moulds were compacted several times using a standard rammer on top of a steel cover in strokes to achieve a particular pressure (3333.3N/M) in the British standard (BS) 2604 part 2 codes of manufacturing particle boards. The moulds were left inside the machine for 30 minutes before been removed. The formed boards were removed from the galvanized steel moulds and the weight of the various boards were taken and recorded respectively. The formed boards were oven dried for 4 hours and the weights were taken and recorded in order to be able to determine the moisture loss in each of the boards. The same procedure was repeated for samples "A B, A C, A D, B C, B D, C D", "A B C, B C D, A C D, A B D" ,"A B C and D" respectively.

3.5 Conditioning (curing)

The production of the board was done after mixing and compacting were due to pressure. The formed boards were removed from the galvanized steel moulds and further oven dried for several hours at temperature of 105^0C. The purpose of conditioning is to have even moisture content through out the board and reduce warpage that might occur due to uneven shrinkage.

3.6 Laboratory Experiment/Tests

Laboratory experiment and tests were carried out according to the method and steps given scientifically. This is to ensure that the results obtained are based on provable principles which originate from facts and figures which guide engineering works. The results obtained from the experiments were subjected to simple statistical analysis.The experiments carried out on the various particle boards are as follows;

i. Moisture content (%)

ii. Porosity (%)

iii. Compressive strength (KN/m)

The experiment procedure, test, and results are observed as follows.

3.6.1 Determination of Moisture Content

To determine the percentage moisture content of the experimental samples of (Rice, sugarcane bagasse, melon shell and sawdust) particles

Apparatus:

i. Samples of Rice, sawdust, melon shell and sugarcane bagasse

ii. Electronic weighing balance

iii. Tin containers labelled A, B, C and D

iv. Electric oven

Procedures

The weights of the various empty containers were taken as (W_1) in each case A, B, C and D. Wet samples of sawdust, sugarcane bagasse, melon shell and rice husk were put in each container and labelled (W_2). The samples were placed in the oven at 105°C for several hours.

The oven dry sample and the container were weighed and recorded as (w_3).The obtained data were used to calculate the percentage of moisture content of the various samples which is given below

$$\frac{W_2-W_3}{W_3-W_1} X \frac{100}{1} \qquad (3.1)$$

3.6.2 Determination of Porosity

Apparatus

i. Weighing balance
ii. Stop Watch
iii. Graduated plastic bucket
iv. Tap water
v. Particle boards

Procedures

The porosity of the various particle boards was determined by finding the bulk density of the individual boards. Bulk density is the ratio of the (bulk weight to bulk volume). It is calculated by dividing the weights of the individual boards by their volume. The formula for calculating bulk density is given below;

$$\text{Bulk Density } \ell_b \text{ in g/cm}^3 = \frac{Mass}{Volume} \qquad (3.2)$$

The volume of the boards was calculated using the volume a cuboids, since the boards are regular in shape. The formula for calculating the volume is given below;

Volume (cm^3) = L x b x h

Where

L = the length of the board in (m)

b = the breadth of the board in (m)

h = the height of the board (m)

The solid density of the individual particle boards was also determined. The solid density ℓ_s in (g/m^3) is calculated by dividing the mass of the individual boards by its volume. The volume of the individual boards was determined by water displacement method which is given as follows:

$$V = \frac{M_W}{\ell_1} \qquad (3.3)$$

Where

Mw = the mass of the particle board weighed in water in (g)

ℓ_1 = the density of water ($1.0 g/cm^3$)

The porosity (%) is calculated using the formula below

$$\varepsilon = 100\left(1 - \frac{\ell_b}{\ell_s}\right) \quad \text{(Mohsenin 1980)} \qquad (3.4)$$

Where

ℓ_b = Bulk density in (g/cm^3)

ℓ_s = Solid density in (g/cm^3)

3.6.3 Determination of the Compressive Strength

Apparatus

Particle boards

Compressive strength testing machine

Procedure: The crushing strength was determined using a manual compressive test machine of weight 126kg and density of 124.5kgcm^2 with a model mark of C90. The machine which is hydraulically operated is equipped with a die gauge, an upper base, and a lower base with a hand lever attached to the side of the compressing machine. During the test, the particle board samples were placed in the machine and the upper base was lowered with the aid of the hand lever so that it forces the sample against the lower base of the machine, this was continued until the sample can no longer withstand the pressure exerted on it by the upper base of the machine. The point at which the sample can no longer withstand the pressure is the point of failure. At this point the sample would either crack or divide into parts. Readings are then taken on the die gauge, which indicates the compressive strength of the sample. This process was repeated for the remaining particle board samples and the results were subjected to simple statistical analysis.

Plate 3.6 Compressive Test for the Formulated Particle Boards

CHAPTER FOUR

4.0 RESULTS

4.1 Presentation of Results

Table 4.1 shows the physical and mechanical properties of formulated particle board using different agricultural wastes. The compressive strength and porosity showed significant relationship ($P<0.05$) for A (Saw dust), B (Sugarcane bagasse), C (Melon shell) and D (Rice Husk)but moisture content of A, B, C and D agricultural wastes did not showed statistical significant different for the samples, The compressive strength of the single formulated agricultural waste ranged from 27KN – 40.00KN. The lowest compressive strength of single formulated particle board was 27KN. The highest compressive strength of single formulated particle board was 40.00KN. The porosity of single formulated particle board from agricultural ranged from 18.60% - 25.00%. The lowest porosity of single formulated particle board was 18.60% while the highest porosity of single formulated particle board was 25.00%. The moisture content of single formulated ranged from 4.10% - 4.80%. The lowest Moisture content of single formulated particle board was 4.10% while the highest moisture content of single formulated particle board was 4.80%

Table 4.1: Physical and mechanical properties of the formulated particle boards using different Agricultural Waste

	Compressive Strength	Porosity (%)	Moisture (%)
A	35.00^{b}	22.80^{b}	4.50^{a}
B	35.50^{b}	25.00^{a}	4.30^{a}
C	27.00^{c}	21.50^{c}	4.10^{a}
D	40.00^{a}	18.60^{d}	4.80^{a}

a, b, c Mean values in the same column followed by different superscript are significantly different from one another ($P<0.05$)

Key

A – Saw dust

B – Sugarcane bagasse

C – Melon shell

D – Rice Husk

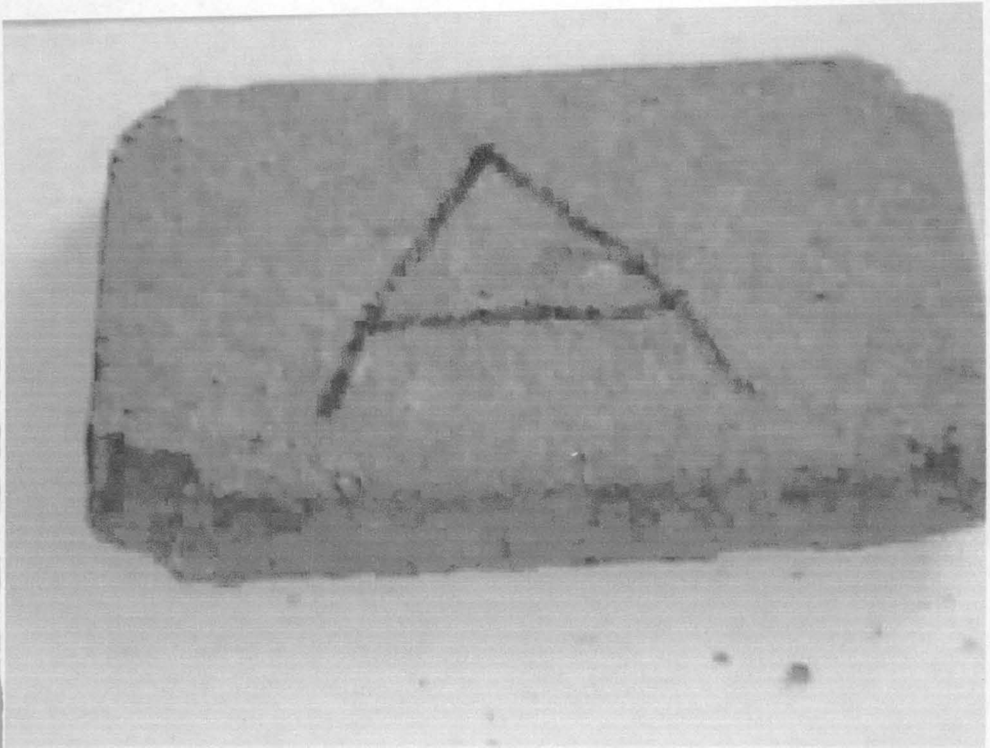

Plate 4.1 Particle Board made from Sawdust

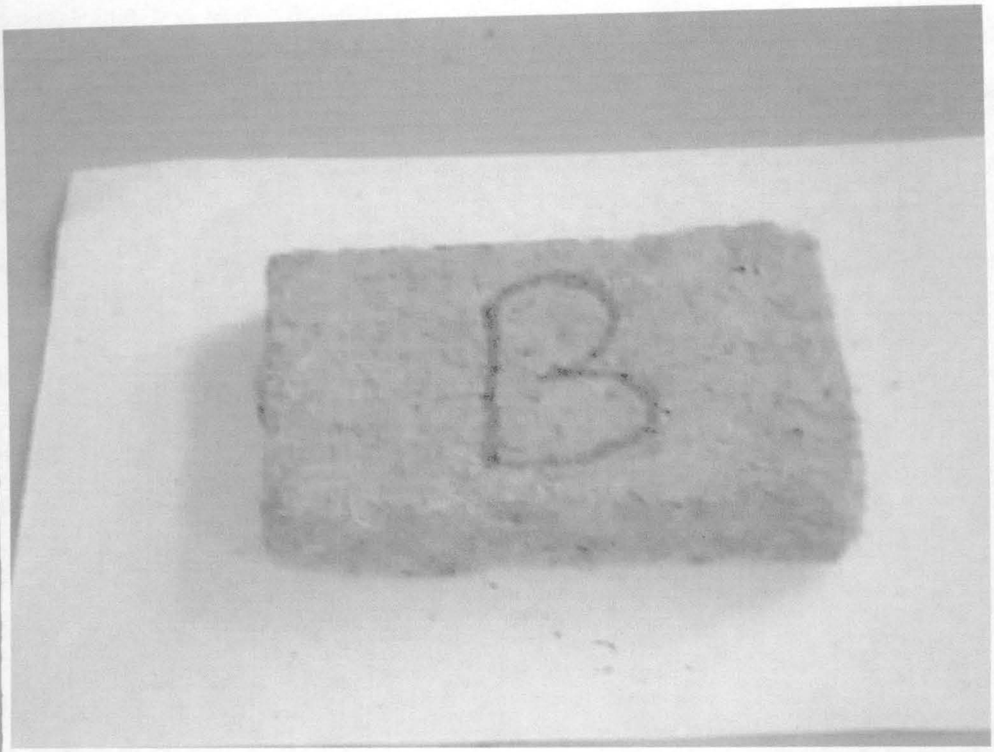

Plate 4.2 Particle Board made from Sugarcane Bagasse

Plate 4.3 Particle Board made from Rice Husk

Table 4.2 shows the physical and mechanical properties of formulated particle board using 2 different agricultural wastes. The compressive strength and porosity showed significant relationship ($P<0.05$) for AB (saw dust + Sugarcane bagasse), AC (Saw dust+ Melon shell), AD (Saw dust + Rice Husk), BC (Sugarcane bagasse + Melon shell), BD (Sugarcane bagasse +Rice Husk), CD (Melon shell + Rice Husk) while the moisture content of AB, AC, AD and BC and BD agricultural wastes did not showed statistical significant different for the samples. The compressive strength of the 2 different formulated agricultural wastes ranged from 29KN – 33.00KN. The lowest compressive strength of 2 different formulated particle boardsfrom agricultural wastes was 29.00KN. The highest compressive strength of the 2 different formulated particle boards was 33.00KN. The porosity of 2 different formulated particle board from agricultural ranged from 11.70% - 28.00%. The lowest porosity of 2 different formulated particle boards was 11.70% while the highest porosity for 2 different formulated particle boards was 28.00%. The moisture content of 2 different formulated ranged from 4.20% - 5.30%. The lowest Moisture content of 2 different formulated particle boards was 4.20% while the highest moisture content of single formulated particle board was 5.30%

able 4.2: Physical and mechanical properties of the formulated particle boards using2 gricultural Wastes

	Compressive Strength	Porosity (%)	Moisture (%)
B	31.00^{b}	22.30^{b}	4.20^{a}
C	33.00^{a}	28.00^{a}	5.10^{a}
D	30.50^{cd}	19.20^{c}	5.30^{a}
C	29.00^{e}	21.60^{b}	5.30^{a}
D	30.00^{cd}	11.70^{d}	5.10^{a}
D	30.00^{cd}	12.50^{c}	4.80^{a}

b, c mean that has different superscript in the same column are statistically different

ey

B – saw dust + Sugarcane bagasse

C – Saw dust+ Melon shell

D – Saw dust + Rice Husk

C –Sugarcane bagasse + Melon shell

) – Sugarcane bagasse +Rice Husk

) – Melon shell + Rice Husk

Plate 4.4 Particle Board made from a mixture of Sawdust and Sugarcane Bagasse

'late 4.5 Particle Board made from a mixture of Sawdust and Rice Husk

Table 4.3 shows the physical and mechanical properties of formulated particle board using 3 and 4 different agricultural wastes. The compressive strength, porosity and moisture showed significant relationship ($P<0.05$) for ABC(Saw dust + Sugarcane bagasse +Melon shell), BCD (Sugarcane bagasse + Melon shell +Rice Husk), ACD (Saw dust+ Melon shell +Rice Husk), ABD (Saw dust+ Sugarcane bagasse+ Rice Husk) and ABCD(Saw dust +Sugarcane bagasse+ Melon shell+ Rice Husk).

Table 4.3: Physical and mechanical properties of the formulated particle boardsusing 3 and 4 agricultural products

	Compressive Strength	Porosity (%)	Moisture (%)
ABC	37.50^{bc}	12.50^{a}	4.90^{a}
BCD	36.50^{c}	5.90^{b}	4.42^{ab}
ACD	38.50^{b}	3.50^{d}	4.40^{ab}
ABD	31.00^{d}	5.10^{bc}	4.23^{ab}
ABCD	42.50^{a}	4.30^{cd}	4.00^{b}

a, b, c mean that has different superscript in the same column are statistically different

Key

ABC – Saw dust + Sugarcane bagasse +Melon shell

BCD – Sugarcane bagasse + Melon shell +Rice Husk

ACD – Saw dust+ Melon shell +Rice Husk

ABD – Saw dust+ Sugarcane bagasse+ Rice Husk

ABCD - Sawdust +Sugarcane bagasse+ Melon shell+ Rice Husk

Plate 4.6 Particle Board made from a mixture Sawdust Sugarcane Bagasse and Rice Husk

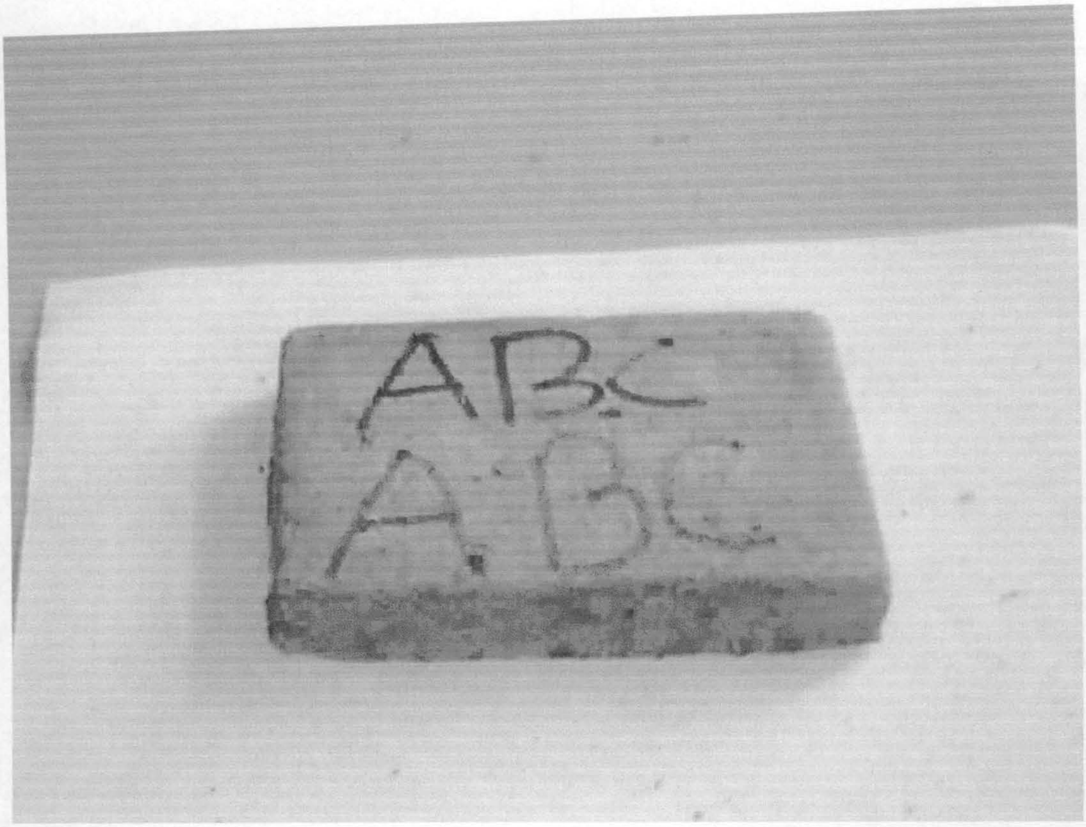

Plate 4.7 Particle boards made from a mixture of Sawdust, Sugarcane bagasse and Melon shell

Plate 4.8 Particle board made from a mixture of Sawdust, Sugarcane bagasse Melon shell and Rice Husk

4.2 Discussion of Results

Table 4.1, 4.2 and 4.3 shows effect of compressive strength on single, 2, 3 and 4 of different formulated particle boards from agricultural wastes. Compressive strength is a measure of the stress at which a material fails under load, while deformation is structural distortion of the material, with or without actual failure. For foamed plastics, fibrous and calcium silicate insulations, compressive strength is typically measured when deformation reaches 5% to 25% of the thickness. The compressive strength results ranged from 27KN – 40.00KN for single formulated (saw dust, sugarcane bagasse, melon shell and rice husk), 2 different formulated (29.00 – 33.00KN) 3 and 4 different formulated 31.00 – 42.50KN. This was in line with the report of ASTM (1992) that said that compressive strength of fibrous glass was 26KN and mineral fiber 59KN. (Jikarn*et al.,* 2006) reported that minimum compressive strength for corrugated board panel was 50 and 70KN this value was higher than all the compressive values obtained in this research work. Compressive strength is a measure of the stress at which a material fails under load, while deformation is structural distortion of the material, with or without actual failure. For foamed plastics, fibrous and calcium silicate insulations, compressive strength is typically measured when deformation reaches 5% to 25% of the thickness. The compressive strength results ranged from 27KN – 40.00KN for single formulated (saw dust, sugarcane bagasse, melon shell and rice husk), 2 different formulated (29 – 33.00KN) 3 and 4 different formulated 31.00 – 42.50KN. This was in line with the report of ASTM (1992) that said that compressive strength of fibrous glass was 26KN and mineral fiber 59KN. (Jikarn*et al.,* 2006) reported that minimum compressive strength for corrugated board panel was 50 and 70KN this values was higher than all the compressive values obtained in this research work.

The moisture content of particle board in this for single, 2 different, 3 and 4 different formulated particles were range from 4.10% - 4.80%, 4.20% - 5.30 and 4.00% - 4.90% respectively. The moisture content of formulated particle board (i.e. saw dust +melon shell, saw dust + rice husk, Sugarcane bagasse + Melon shell and Sugarcane bagasse + Rice Husk) were within the standard range of ASTM (1992) 5 – 8% and this was also in line with (Anbu *et al.,* 2009) who reported 5 – 6% of particle board from rice husk and reported moisture content of 5 – 8% for particle board. The moisture content of single, 3 and 4 moisture content of the particle were below the ASTM (1992).

Particleboard, like other wood based products and many other building materials, will respond to changes in relative humidity of the surrounding air. Board dimensions are closely related to moisture content. Conditions likely to change the moisture content above or below the 8-12% range normally applying at dispatch from the factory, may give rise to problems. Particleboard should be conditioned to reach the humidity level in which it is to be used. Moisture content will normally be in the range 10-12% when used in buildings intended for human occupancy. The porosity for single, 2 different, 3 different formulated particle boards were18.60% - 25.00, 11.70% - 28.00% and 4.30 – 12.50% respectively. The porosity of single and double was in line with the report of USDA (2007). The USDA (2007) reported that the porosity of plywood and particle board should be between 16 – 30%. Some of these formulated particle board were within the range recommended by USDA (2007).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

ABC – Saw dust + Sugarcane bagasse + Melon shell, BCD – Sugarcane bagasse + Melon shell + Rice Husk, ACD – Saw dust + Melon shell + Rice Husk, ABD – Saw dust + Sugarcane bagasse + Rice Husk and ABCD Saw dust + Sugarcane bagasse + Melon shell + Rice Husk can be utilised in the manufacture of particleboards, ceiling boards and insulation boards. The use of biodegradable adhesives (gum Arabic) could reduce the use of synthetic adhesives based on petroleum resources and its ill effects. These materials could provide competitive composite boards for construction and, at the same time, be environmentally friendly. Developing countries like Nigeria should make an effort to harness the potential of the abundantly available this formulation. Efficient utilisation could serve as revenue for the nation. Since the construction industry is a growing industry, the use of renewable resources such as ABC – Saw dust + Sugarcane bagasse + Melon shell, BCD – Sugarcane bagasse + Melon shell + Rice Husk, ACD – Saw dust + Melon shell + Rice Husk, ABD – Saw dust + Sugarcane bagasse + Rice Husk and ABCD Saw dust + Sugarcane bagasse + Melon shell + Rice Husk can reduce the strain on forest resources and for man excellent replacement for wood and wood based composite materials.

5.2 Recommendations

It is hereby recommended that:

i. ABC – Saw dust + Sugarcane bagasse + Melon shell, BCD – Sugarcane bagasse + Melon shell + Rice Husk, ACD – Saw dust + Melon shell + Rice Husk, ABD – Saw dust + Sugarcane bagasse + Rice Husk and ABCD Saw dust + Sugarcane bagasse + Melon shell + Rice Husk should be used for particle board production because it showed statistically significant difference.

ii. The extraction process of Gum Arabic should be improved upon in order to prevent it from been contaminated with foreign materials.

iii. Oven drying should be employed for several hours at temperature of 105^0C for proper curing of the particle board.

iv. A local medium production plant should be established for the production of particle boards on the recommended design should include;

Drying process → crushing→ mixture processing→ delignification→ compaction→ oven drying→ finishing processing, there by effectively utilizing agricultural wastes and reducing the increasing demands on plywood.

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APPENDICES

APPENDIX I Descriptive Statistics

criptive Statistics for Single Formulated Particle Boards

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
pressive_ gth	A	3	35.0000	1.00000	.57735	32.5159	37.4841	34.00	36.00
	B	3	35.5000	.10000	.05774	35.2516	35.7484	35.40	35.60
	C	3	27.0000	.01000	.00577	26.9752	27.0248	26.99	27.01
	D	3	40.0000	1.00000	.57735	37.5159	42.4841	39.00	41.00
	Total	12	34.3750	4.92750	1.42245	31.2442	37.5058	26.99	41.00
sity	A	3	22.8000	.10000	.05774	22.5516	23.0484	22.70	22.90
	B	3	25.8000	1.00000	.57735	23.3159	28.2841	24.80	26.80
	C	3	21.5000	.10000	.05774	21.2516	21.7484	21.40	21.60
	D	3	18.6000	.01000	.00577	18.5752	18.6248	18.59	18.61
	Total	12	22.1750	2.73600	.78982	20.4366	23.9134	18.59	26.80
ure_cont	A	3	4.5000	.01000	.00577	4.4752	4.5248	4.49	4.51
	B	3	4.3000	.01000	.00577	4.2752	4.3248	4.29	4.31
	C	3	4.1000	1.00000	.57735	1.6159	6.5841	3.10	5.10
	D	3	4.8000	.10000	.05774	4.5516	5.0484	4.70	4.90
	Total	12	4.4250	.50658	.14624	4.1031	4.7469	3.10	5.10

```
ONEWAY Compressive_strength Porosity Moisture_content by Factor
  /STATISTICS DESCRIPTIVES
  /MISSING ANALYSIS
  /POSTHOC=DUNCAN ALPHA(0.05)
```

nalysis of Variance for single Formulated Boards

		Sum of Squares	df	Mean Square	F	Sig.
npressive_stren	Between Groups	263.062	3	87.688	174.494	.000
	Within Groups	4.020	8	.503		
	Total	267.083	11			
osity	Between Groups	80.303	3	26.768	104.960	.000
	Within Groups	2.040	8	.255		
	Total	82.343	11			
sture_content	Between Groups	.803	3	.268	1.059	.419
	Within Groups	2.020	8	.253		
	Total	2.823	11			

Post Hoc Tests

Homogeneous Subsets

Duncan Multiple Range Test for Compressive Strength for

Two Formulated Particle Boards

factor	N	Subset for alpha = 0.05		
		1	2	3
C	3	27.0000		
A	3		35.0000	
B	3		35.5000	
D	3			40.0000
Sig.		1.000	.413	1.000

Means for groups in homogeneous subsets are displayed.

N = Number of replicated boards

Sig = Significance level

Duncan Multiple Range Test for Porosity for

Two Formulated

Particle Boards

Factor	N	Subset for alpha = 0.05			
		1	2	3	4
D	3	18.6000			
C	3		21.5000		
A	3			22.8000	
B	3				25.0000
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

Duncan Multiple Range Test for Two Moisture Content for Two Formulated Particle Boards

Factor	N	Subset for alpha = 0.05
		1
C	3	4.1000
B	3	4.3000
A	3	4.5000
D	3	4.8000
Sig.		.147

Means for groups in homogeneous subsets are displayed.

'ysis of Variance for Two Formulated Particle Boards

		Sum of Squares	df	Mean Square	F	Sig.
pressive_strength	Between Groups	27.625	5	5.525	5.525	.007
	Within Groups	12.000	12	1.000		
	Total	39.625	17			
sity	Between Groups	544.045	5	108.809	108.809	.000
	Within Groups	12.000	12	1.000		
	Total	556.045	17			
ure_content	Between Groups	2.620	5	.524	.786	.579
	Within Groups	8.000	12	.667		
	Total	10.620	17			

Post Hoc Tests

Homogeneous Subsets

Duncan Multiple Range Test for Compressive Strength For Three Formulated Particle Boards

Factor	N	Subset for alpha = 0.05		
		1	2	3
D	3	29.0000		
E	3	30.0000	30.0000	
F	3	30.0000	30.0000	
C	3	30.5000	30.5000	
A	3		31.0000	
B	3			33.0000
Sig.		.114	.278	1.000

Means for groups in homogeneous subsets are displayed.

Duncan Multiple Range Test for Porosity for Three Formulated Particle Boards

Factor	N	Subset for alpha = 0.05				
		1	2	3	4	5
E	3	11.7000				
F	3		12.5000			
C	3			19.2000		
D	3				21.6000	
A	3				22.3000	
B	3					28.0000
Sig.		1.000	1.000	1.000	.408	1.000

Means for groups in homogeneous subsets are displayed.

Duncan Multiple Range Test for

Moisture Content for Three

Formulated Particle Boards

Factor	N	Subset for alpha = 0.05
		1
A	3	4.2000
F	3	4.8000
B	3	5.1000
E	3	5.1000
C	3	5.3000
D	3	5.3000
Sig.		.161

Means for groups in homogeneous subsets are displayed.

Oneway

scriptive Statistics For Three Formulated Particle Boards

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
npressive ngth	1	3	37.5000	1.00000	.57735	35.0159	39.9841	36.50	38.50
	2	3	36.5000	.00000	.00000	36.5000	36.5000	36.50	36.50
	3	3	38.5000	.01000	.00577	38.4752	38.5248	38.49	38.51
	4	3	31.0000	.00000	.00000	31.0000	31.0000	31.00	31.00
	5	3	42.5000	1.00000	.57735	40.0159	44.9841	41.50	43.50
	Total	15	37.2000	3.87667	1.00095	35.0532	39.3468	31.00	43.50
sity	1	3	12.5000	.00000	.00000	12.5000	12.5000	12.50	12.50
	2	3	5.9000	.01000	.00577	5.8752	5.9248	5.89	5.91
	3	3	3.5000	1.00000	.57735	1.0159	5.9841	2.50	4.50
	4	3	5.1000	.01000	.00577	5.0752	5.1248	5.09	5.11
	5	3	4.3000	.00000	.00000	4.3000	4.3000	4.30	4.30
	Total	15	6.2600	3.35534	.86635	4.4019	8.1181	2.50	12.50
ture_cont	1	3	4.9000	.01000	.00577	4.8752	4.9248	4.89	4.91
	2	3	4.4200	.00000	.00000	4.4200	4.4200	4.42	4.42
	3	3	4.4000	1.00000	.57735	1.9159	6.8841	3.40	5.40
	4	3	4.2300	.01000	.00577	4.2052	4.2548	4.22	4.24
	5	3	4.0000	.00000	.00000	4.0000	4.0000	4.00	4.00
	Total	15	4.3900	.48674	.12568	4.1205	4.6595	3.40	5.40

Analysis of Variance for Three Formulated Particle Boards

		Sum of Squares	df	Mean Square	F	Sig.
mpressive_stren	Between Groups	206.400	4	51.600	128.994	.000
	Within Groups	4.000	10	.400		
	Total	210.400	14			
rosity	Between Groups	155.616	4	38.904	194.481	.000
	Within Groups	2.000	10	.200		
	Total	157.616	14			
isture_content	Between Groups	1.316	4	.329	1.645	.238
	Within Groups	2.000	10	.200		
	Total	3.317	14			

Post Hoc Tests

Homogeneous Subsets

Compressive strength

Duncan

Factor	N	Subset for alpha = 0.05			
		1	2	3	4
4	3	31.0000			
2	3		36.5000		
1	3		37.5000	37.5000	
3	3			38.5000	
5	3				42.5000
Sig.		1.000	.082	.082	1.000

Means for groups in homogeneous subsets are displayed.

Porosity

Duncan

Factor	N	Subset for alpha = 0.05			
		1	2	3	4
3	3	3.5000			
5	3	4.3000	4.3000		
4	3		5.1000	5.1000	
2	3			5.9000	
1	3				12.5000
Sig.		.053	.053	.053	1.000

Means for groups in homogeneous subsets are displayed.

Moisture Content

Duncan

Factor	N	Subset for alpha = 0.05	
		1	2
5	3	4.0000	
4	3	4.2300	4.2300
3	3	4.4000	4.4000
2	3	4.4200	4.4200
1	3		4.9000
Sig.		.308	.118

Means for groups in homogeneous subsets are displayed.

Appendix II Porosity Determined

In calculating the porosity of the dried particle board, the bulk density in g/cm^3 and the solid density in g/cm^3 are very important.

Porosity $\varepsilon = 100\ (1 - \frac{\ell_b}{\ell_s})$

Where

ℓ_b =Bulk density

ℓ_s= solid density

Bulk density (ℓ_b) in g/cm^3 = $\frac{Mass}{Volume}$

But volume is = L× b× h

150mm×100× 20mm = 3000,000 mm^3

Converting to cm^3

1mm = 0.1 cm

1mm^3 = 0.1cm× 0.1cm × 0.1cm

1mm^3= 0.001cm^3

Therefore the volume of the board will be

0.001× 300,000mm^3 = 300cm^3

Sample A (ℓ_b) = $\frac{171.50g}{300\ cm^3}$ = 0.572g/cm^3

(ℓ_s) = $\frac{171.50g}{231.38\ cm^3}$ = 0.7412g/cm^3

$100 = (1 - \frac{0.5720}{0.7412}) = 22.8\%$

Sample B $(\ell_b) = \frac{204.10g}{300\,cm^3} = 0.6803 g/cm^3$

$(\ell_s) = \frac{204.10g}{225.01cm^3} = 0.9071 g/cm^3$

$\varepsilon = 100\,(1 - \frac{0.6803}{0.9071}) = 25.0\%$

Sample C $(\ell_b) = \frac{196.46g}{300\,cm^3} = 0.6548 g/cm^3$

$(\ell_s) = \frac{196.46g}{235.54c\,cm^3} = 0.8340 g/cm^3$

$\varepsilon = 100\,(1 - \frac{0.6548}{0.8340}) = 21.5\%$

Sample D $(\ell_b) = \frac{256.30g}{300\,cm^3} = 0.8543 g/cm^3$

$(\ell s) = \frac{256.30g}{315.20cm^3} = 0.8131 g/cm^3$

$\varepsilon = 100\,(1 - \frac{0.8543}{0.8131}) = 18.6\%$

Sample AC $(\ell b) = \frac{194.58g}{300\,cm^3} = 0.6486 g/cm^3$

$(\ell_s) = \frac{194.58g}{215.15cm^3} = 0.9043 g/cm^3$

$\varepsilon = 100(1 - \frac{0.6486}{0.9043}) = 28\%$

Sample AD $(\ell_b) = \frac{223.60g}{300\,cm^3} = 0.7453 g/cm^3$

$(\ell_s) = \frac{223.60g}{242.38cm^3} = 0.9225 g/cm^3$

$\varepsilon = 100\ (1 - \frac{0.7453}{0.9225})\ 19.2\%$

Sample BC $(\ell_b) = \frac{208.9g}{300\ cm^3} = 0.6963 g/cm^3$

$(\ell_s) = \frac{208.9g}{300\ cm^3} = 0.8883 g/cm^3$

$\varepsilon = 100\ (1 - \frac{0.6963}{0.8883}) = 21.6\%$

Sample CD $(\ell_b) = \frac{262.70g}{300\ cm^3} = 0.8756 g/cm^3$

$(\ell_s) = \frac{262.70g}{335.38 cm^3} = 0.7832 g/cm^3$

$\varepsilon = 100\ (1 - \frac{0.8756}{0.7832}) = 11.70\%$

Sample ABC $(\ell_b) = \frac{225.54g}{300\ cm^3} = 0.7518 g/cm^3$

$(\ell_s) = \frac{225.54g}{262.44 cm^3} = 0.8593 g/cm^3$

$\varepsilon = 100\ (1 - \frac{0.7518}{0.8593}) = 12.5\%$

Sample BCD $(\ell_b) = (\frac{242.49g}{300\ cm^3})\ 0.8033 g/cm^3$

$(\ell_s) = \frac{242.49g}{284.03 cm^3} = 0.8537$

$\varepsilon = 100\ (1 - \frac{0.8033}{0.8537}) = 5.9\%$

Sample ACD $(\ell_b) = \frac{268.54g}{300\ cm^3} = 0.8951 g/cm^3$

$(\ell_b) = \frac{268.54g}{292.49 cm^3} = 0.9181 g/cm^3$

$\varepsilon = 100\ (1- \frac{0.8951}{0.9181}) = 3.5\%$

Sample ABD (ℓb) = $\frac{274.98g}{300\ cm^3}$ = $0.9166 g/cm^3$

(ℓ_s) = $\frac{274.98g}{284.61 cm^3}$ = $0.9661 g/cm^3$

$\varepsilon = 100\ (1- \frac{0.9166}{0.9661}) = 5.1\%$

Sample ABCD (ℓ_b) = $\frac{258.05g}{300\ cm^3}$ = $0.8601 g/cm^3$

(ℓ_s) = $\frac{258.05g}{286.90\ cm^3}$ = 0.8994

$100\ (1- \frac{0.8601}{0.8994}) = 4.3\%$

Appendix III Moisture Content Determined

In calculating moisture content of the dried particle board, the weight of the board and the amount of moisture removed is very important.

Moisture content dry basis (%) = $\frac{W_2 - W_3}{W_3 - W_1} \times 100$

Where

W_1 = weight of container (g)

W_2 = weight of wet sample + container (g)

W_3 = weight of dried sample + container (g)

(W_2-W_3) g = weight of moisture

Sample A = $\frac{45.87-45.01}{45.01-26.00} \times 100 = 4.5\%$

Sample B = $\frac{46.70-44.55}{44.55-25.05} \times 100 = 4.21\%$

Sample C = $\frac{48.42-47.60}{47.60-25.30} \times 100 = 4.10$

Sample D = $\frac{50.74-49.54}{49.54-24.46} \times 100 = 4.78\%$

Sample AB= $\frac{46.37-44.55}{44.55-25.05} \times 100 = 4.2O\%$

Sample AC = $\frac{51.81-50.48}{50.48-26.02} \times 100 = 5.1\%$

Sample AD = $\frac{50.50}{49.20} \times 100 = 5.05\%$

Sample BC= $\frac{51.36-50.4}{50.04-23.5} \times 100 = 5.05\%$

Appendix IV Density Determined

In calculating the density of the dried particle board, the weight of the formed board per unit volume is very important.

Density = $\frac{Mass}{Volume}$

Sample A = $\frac{0.1715}{3.00\times10^{-4}}$ = 571.6 kg/m^3

Sample B = $\frac{0.2041}{3.00\times10^{-4}}$ = 680.3 kg/m3

Sample C = $\frac{0.19646}{3.00\times10^{-4}}$ = 654.9 Kg/m^3

Sample ... $3.00\times10^{-}$

Sample ... $3.00\times10^{-}$

Sample AC = $\frac{0.19458}{3.00\times10^{-}}$ = 648.6 Kg/m^3

Sample AD = $\frac{0.2236}{3.00\times10^{-4}}$ = 745.3 Kg/m^3

Sample BC = $\frac{0.2089}{3.00\times10^{-4}}$ = 696.3Kg/m^3

Sample BD = $\frac{0.23561}{3.00\times10^{-4}}$ = 785.4 Kg/m^3

Sample CD = $\frac{0.2627}{3.00\times10^{-4}}$ = 875.7 Kg/m^3

Sample ABC = $\frac{225.54}{3.00\times10^{-4}}$ = 751.8 Kg/m^3

Sample BCD = $\frac{0.27249}{3.00\times10^{-4}}$ = 908.3Kg/m^3

Sample ACD = $\frac{0.2658}{3.00\times10^{-4}}$ = 895.1 Kg/m^3

Sample ABD = $\frac{0.27.98}{3.00\times10^{-4}}$ = 916.6 Kg/m^3

Sample ABCD = $\frac{0.25805}{3.00\times10^{-4}}$ = 860.2 Kg/m^3

Appendix V Compaction

Using a 50Kg standard rammer, with an applied distance of 0.10m iron mould pallet to compact the particle board mixture, The force of application can be calculated as:

Compaction Force = $\frac{Mass}{Applied\ distance}$ (Kg) × acceleration due to gravity = 500Kg × 10 = 5000N

Pressure = $\frac{Force}{Area}$ = N/m^2

= $\frac{5000}{(0.15 \times 0.1)}$ =3333.3 N/m^2