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PHYSICAL AND MECHANICAL PROPERTIES OF BINDERLESS HETAL (*Phoenix paludosa*) FIBERBOARD

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COURSE NO: FWT-4114

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DECLARATION

I hereby declare that this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted to other degree at Khulna University or other institutions.

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Dedicated

To

My Beloved Parents

ACKNOWLEDGEMENT

First of all, I am very grateful to almighty Allah for successfully completion of my B. Sc. honour's project thesis. I would like to thank and express my gratitude to several people.

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The Author

Md. Zohurul Islam

ABSTRACT

The present study was conducted to evaluate the physical and mechanical properties of binderless Hetal *(Phoenix paludosa)* fiberboard and the manufacturing process of fiberboard. Two types of binderless Hetal fiberboard were produced under two different fiber pretreatment processes (grinding and boiling).The fiber pretreatments (grinding and boiling) effect on the properties of Hetal binderless fiberboard. It was found that the boiling pretreatment has significant negative effect on the properties of Hetal binderless fiberboard. Boiling treated fiberboard showed very poor result but fiberboard with grinded fibers showed better physical and mechanical properties that satisfied the standard value of ANSI. The manufactured boards under grinding treatment and boiling treatment showed board density of 0.78 g/cm^3 and 0.72 g/cm^3 respectively. The moisture content of binderless Hetal fiberboard of grinding and boiling treated fibers was found 8.88% and 11.73% respectively. The measured MOR of grinded Hetal fiberboard was 11.75 N/mm^2 and fiberboard with boiling fibers showed MOR of 7.20 N/mm^2. The modulus of elasticity (MOE) of grinded and boiling fiberboards was found 1695 N/mm^2 and 1170 N/mm^2 respectively. The MOR and MOE of Medium Density Fiberboard (MDFB) were found 11 N/mm^2 and 1725N/mm^2 (ANSI A208.1-1993) respectively. The density, moisture content, Modulus of Rapture (MOR) and Modulus of Elasticity (MOE) of Hetal binderless fiberboard with grinded fibers was very close to the standard value of ANSI for medium density fiberboard.

TABLE OF CONTENTS

LIST OF FIGURES

ABBREVIATION

Anon	Anonymous
ANOVA	Analysis of Variance
LSD	Least Significant Difference
APCC	Asian and Pacific Coconut Community
ASTM	American Society for Testing and Materials
AWPA	Australian Wood Panels Association
BBS	Bangladesh Bureau of Statistics
FAO	Food and Agricultural Organization of United Nations
g/cm^3 or gm/cm^3	Gram per cubic centimeter
Ha	Hectare
kg/m^3	Kilogram per cubic meter
KN	Kilo Newton
lb/ft^3	Pound per cubic feet
cm	Centimeter
m	Meter
mm	Millimeter
µm	Micro meter
MOE	Modulus of Elasticity
MOR	Modulus of Rupture
MPa	Mega Pascal
N/mm^2	Newton per square millimeter
PVC	Poly vinyl chloride
PP	Polypropylene
PVAC	Poly-vinyl acetate
rpm	Rotor per minute
SD	Standard deviation
UTM	Universal Testing Machine
WP	Wood particle

Chapter One

Introduction

1.1 Background of the Study

The population of the world is increasing day by day and at the same time the forest is decreasing at an alarming rate. So people want fiber products at lower prices. That's why different composites are invented to fulfill people's demands. Fiberboard is one of the great examples of these composites.

The continuing global loss of forests is a major concern to governments worldwide. The inexorable increase in world population, together with shifting climatic patterns, will put more pressure on the land to sustain local communities which rely on forest products of various kinds. There will be challenges in expanding the ability of forests to meet the needs of societies worldwide. To meet the demand of expanding pressure, alternative raw materials are major concern of the world.

Fiberboards have some advantages over massive wood such as their homogenous structure in every direction and do not contain defects such as knots, fiber distortion and decay encountered in massive wood. It is possible to manufacture larger dimension boards. Nailing, screwing are easily made. Painting, covering, machining, varnishing and carving are also easily applied. In addition, resistance against fungi, insects and fire can be obtained by using certain chemical substances. Whereas, massive wood is an anisotropic material. It contains heartwood, sapwood, springwood, summerwood, young wood, knots, fissures and other pathological defects.

Therefore, it expands differently in the radial, tangential and longitudinal directions. As a result, it may be bended, distorted and undulated. In addition, fiberboards have more uniform structure than other wood based panels such as wafer board, strand board, flake board and particleboard. Besides, a wide range of lower value raw material can be used in the manufacture of Fiberboard (Eroglu, 1988; Rowell, 1992).

On the other hand, the wood based industries in Bangladesh faced badly a hard situation of great lacking of available raw materials. But due to heavy industrial development, the wood based composites such as hard board; fiber boards etc. are in high demand and have to be supplied successively. So it is now very much essential to find out the alternative raw materials for these industries, not only to meet the demand but also to reduce the pressure on the presently used tree species by these industries.

Bangladesh has the world's largest single tract mangrove forest. Hetal is one of the species of Sundarbans. It has great potential to produce particleboard. It contains about 26% lignin content. So it can be a source of binderless fiberboard. In terrestrial area it shows high growth performance. As it is binderless fiberboard, so it can be very economic.

Bangladesh is a densely populated country. The problem of housing is becoming more and more acute with the increase in nits population. Moreover, natural disaster like flood is very frequent and humid weather prevails in most part of the year. The situation, therefore, demands low cost housing for the teeming millions that would very likely promote the use of inorganic bonded panels as cheap construction materials. In this context, the present study is undertaken to evaluate the suitability of Hetal *(Phoenix paludosa)* in the fabrication of binderless wood composites.

1.2 Objectives of the Study

The study consisted of the following specific objectives:

- To assess the technical feasibility of Hetal *(Phoenix paludosa)* as a raw material for manufacturing binderless fiberboard.
- To evaluate the physical and mechanical properties of Hetal binderless fiberboard.
- To compare the physical and mechanical properties of Hetal binderless fiberboard with the standard value of ANSI for medium density fiberboard.

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CHAPTER TWO

Review of Literature

2.1 WOOD

2.1.1 PHYSICAL COMPOSITION

Wood (xylem) is composed of elongated cells; they are oriented in the longitudinal direction of the stem (Figure 2.1). The ends are connected through openings, and these openings are called pits. These cells vary in function and differ in shape. They perform in the transport of liquid and act as food reserves. They also provide necessary mechanical support to the tree (Eero Sojstrom, 1993).

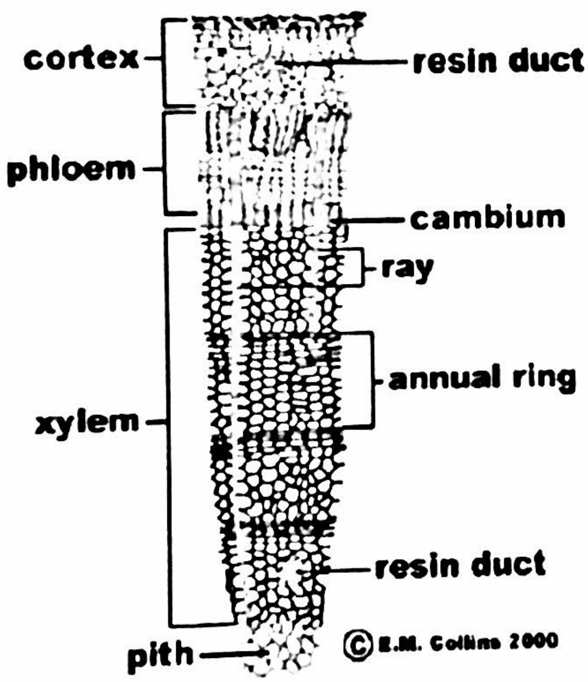

Figure 2.1 Diagram showing a section of a dicot stem

2.1.2 XYLEM ULTRA STRUCTURE

The xylem cells consist mainly of cellulose, hemicellulose, and lignin. Cellulose is comprised of a crystalline structure, while hemicellulose has a semi-crystalline structure and lignin is an amorphous polymer. The cell wall is built up by several layers, namely the middle lamella (ML), primary wall (P), outer layer of the secondary wall (S1), middle layer of secondary wall (S2), inner layer of the secondary wall (S3) and warty layer (W) (Figure 2.2). These layers differ from each other based on their chemical composition and their structure. The ML is located between the cells and serves the function of binding wood cells together. Though it contains pectin in the initial stages it becomes lignified in later stage of life (Fengel and Wegener, 1983).

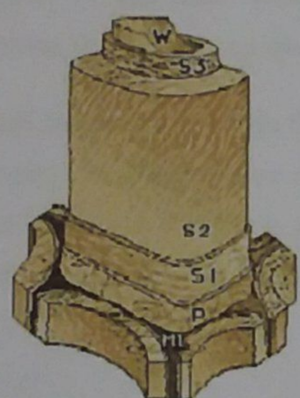

Figure 2.2 Structure of wood cell, showing the middle lamella (ML), primary wall (P), outer (S1), middle (S2) and inner (S3) layers of secondary cell wall and the warty layer (W).

2.1.3 CHEMICAL COMPOSITION

Wood is a lignocellulosic material and is composed of approximately 50-65% cellulose, 20-25% lignin and 1-10% extractives and traces of ash. The ratio of constituents differs based on species. The absorption of water by cellulose depends on the number of hydroxyl groups that are not linked with other hydroxyl groups. Usually, the crystalline structure of cellulose will not take part in chemical reaction because of it unavailable hydroxyl groups but only the amorphous region (Fengel and Wegener, 1983).

2.2 Detail Information about Fiberboard

2.2.1 Fiberboard

Fiberboard is an industrial product manufactured by drying and pressing of wet board obtained from vegetative fibers and fiber bundles having natural bonding and felting properties or by means of additional adhesives. In other words, it is a board obtained by the rearrangement of lignocellulosic fibers and fiber bundles. Medium Density Fiberboard is obtained from thermo-mechanically produced fibers after 9-11 % adhesive addition, drying and hot pressing. Physical and mechanical properties of fiberboard depends on specific gravity and fiber properties such as fiber length, fiber width, lumen diameter and the amount of additive used. As well as, fiberboard manufacturing method, preparation of wet web, pressing time, pressure, temperature and finishing treatments profoundly affect its physical and mechanical properties (Eroglu, 1988).

Fiberboard industry was developed in conjunction with the paper industry. Paper manufacturing from wood pulp is about 150 years old. Manufacture of first isolation board realized during World War I. whereas, the first hardboard plant was built in 1926. Later, Medium Density Fiberboard (MDF-dry) developed in the United States in 1965 (Suchsland and Woodson, 1986).

2.2.2 Types of Fiberboard

There are different types of fiberboard depending on density and specific gravity.

2.2.2.1 Depending on density, fiberboard can be classified as follow:

I. **Soft board:** Soft board is a board having a density up to 250Kg/m^{3}.
II. **Medium board:** A board having a density between 350Kg/m^{3} and 800Kg/ m^{3} is classified as medium board.
III. **Hard board:** Hard board is also a fiberboard having a density above 800Kg/ m^{3} is classified as hard board. (Youngquist, 1999).

2.2.2.2 According to Anon (1985), fiberboards are classified into three types:

I. **Soft board:** The board having density less than 400K g/m^{3}.
II. **Wall board:** The board having a density between 400Kg/m^{3} and 481Kg/ m^{3}.
III. **Hard board:** The board having density not less than 481K g/m^{3}.

2.2.2.3 There are another three types of fiberboard depending on the specific gravity:

1. Low Density Fiberboard (LDF)

Low density fiberboards have a specific gravity of between 0.15 and 0.45 and are used for insulation and for light-weight cores for furniture. They are usually produced by a dry process that uses a ground wood fiber (Berglund and Rowell, 2005; Youngquist, 1999).

2. Medium Density Fiberboard (MDF)

Medium density fiberboards have a specific gravity of between 0.6 and 0.8 and are frequently used in place of solid wood, plywood and particle board in many furniture applications. It is also used for interior door skins, moldings and interior trim components (Berglund and Rowell, 2005; Youngquist, 1999).

3. High Density Fiberboard (HDF)

High density fiberboards have a specific gravity of between 0.85 and 1.2 and are used as an overlay on workbenches and floors and for siding. It is produced both with and without wax and sizing agents. The wax is added to give the board water resistance (Berglund and Rowell, 2005; Youngquist, 1999).

2.2.3 General Manufacturing Steps of Fiberboard

2.2.3.1 Methods of Fiber Production

Fibers are made by various mechanical pulping methods or by explosion process.

2.2.3.1.1 Mechanical Pulping

There are broadly two methods for the production of mechanical pulp. One is the grinding of debarked logs and the other is the refining of wood chips and agricultural residues.

Wood can be broken down into fiber bundles or single fibers by grinding or refining. In the grinding process, the wood is mechanically broken down into fibers. In refining process, wood chips are placed between one or two rotating plates in a wet environment and broken down into fibers. If the refining is done at high temperature, the fibers tend to slip apart as a result of the softening of lignin between the fibers and consequently the fiber will have a lignin reach surface. If the refining is done at low temperature, the fibers tend to break apart and the surface is rich in carbohydrate polymers.

Traditional mechanical pulping involves forcing logs against a revolving stone, which grinds the logs into pulp by abrasive action. The stone is sprayed with water to remove fibers from the pulp stone, and to prevent fiber damage due to friction-generated heat. The production of mechanical pulp results in little removal of lignin content, and consequently produces paper that is not of as high a quality as other pulping methods that remove significant amounts of lignin. The advantages of mechanical pulping are its high pulp yield (100 pounds of wood can generate as much as 95 pounds of pulp), its low cost, and the paper it produces has several desirable printing qualities, such as high ink absorbency, compressibility, opacity, and bulk. Disadvantages, however, include low strength, low permanence, and a tendency to yellow with time (primarily caused by high levels of lignin). Paper made with mechanical pulps also contain shives, or incompletely ground fiber bundles.

The other method involves either treatment of the wood chips or agricultural residues with chemical or thermal pretreatment prior to pulping in disk refiners or attrition mills. Solid wood is debarked and then chipped in a chipper and screened. The coarse chips are rechipped and fines sent to the boiler. In the chemi-mechanical pulping, neutral sulphite cook, sodium hydroxide cook or a lime cook is used. Thermo-mechanical pulping is based on the softening of the middle lamella or inter cellular layers between the fibers due to heating 150^0c to 180^0c. This facilitates separation of fiber. The chemical composition of the pulp remains almost identical to that of the original wood or other ligno-cellulosic materials. The original fiber structure is also preserved and very high yield, 90to 93 percent is obtained (Salehuddin, 1992).

2.2.3.1.2 Explosion process

This process is better known as the Masonite process. Here 100kg of wood chips or agricultural residues are charged into a high pressure cylinder called a 'Gan' and steam is admitted. The pressure is raised to 40kp/cm in about 30 seconds. After a steaming period of another 30 seconds under this pressure is quickly raised to 70 to 80 kp/cm, raising the temperature to 285^0c to 295^0c held for only about 5 seconds, before suddenly releasing the pressure by a hydraulically operated quick opening value. The 'gans' blown first under the influenced of high steam pressure, moisture, and high temperature, the wood under goes a hydrolytic reaction which breaks down the lingo-cellulosic bond. Secondly, the sudden release of the hydrolyzed chips to atmospheric pressure tears them spart to produce a characteristically blows , fluffy fiber the fibers are washed with clean hot water to remove hydrolytic products and before mat formation (Salehuddin, 1992).

2.2.3.2 Methods of Mat Formation

Mat is formed by wet, dry or semi dry processes. Fiberboard is normally classified by density and can be made by either dry or wet processes. Dry processes are applicable to boards with high density (hardboard) and medium density fiberboard (MDF). Wet processes are applicable to both high density fiberboard and low density insulation board. The manufacturing of high and medium density dry process and wet process fiberboards are briefly described below:

2.2.3.2.1 Dry Process

Dry process fiberboards are made in a similar fashion to particleboards. Resin (UF, PF) and other additives may be applied to the fibers by spraying in short retention blenders, or introduced as the wet fibers from the refiner are fed into a blow line dryer. Alternatively, some fiberboard plants add the resin in the refiner. The adhesive coated fibers are then air-laid into a mat for subsequent pressing much the same as particleboard. Pressing procedures for dry process fiberboards differ somewhat from particleboards. After the fiber mat is formed, it is typically prepressed in a band press. The densified mat is then trimmed by disc cutters and transferred to caul plates for the pressing operation. Dry-formed boards are pressed in multi-opening presses with temperatures of around 190^0–210°C. Continuous-pressing large, high pressure band presses are also gaining in popularity. Board density is a basic property and is an indicator of board quality. Moisture content greatly influences density; thus, the moisture content is constantly monitored by moisture sensors using infrared light (Suchsland and Woodson, 1986; Maloney, 1993).

2.2.3.2.2 Wet Process

Wet process hardboards differ from dry process fiberboards in several significant ways. First, water is used as the distribution medium for the fibers to be formed into a mat. As such, this technology is really an extension of paper manufacturing technology. Secondly, some wet process boards are made without additional binders. If the lignocellulosic contains sufficient lignin, and if the lignin is retained during the refining operation, the lignin can serve as the binder. Under heat and pressure, the lignin will flow and act as a thermosetting adhesive, enhancing the naturally occurring hydrogen bonds. Refining is an important step for the development of strength in wet process hardboards. The refining operation must also yield a fiber of high "freeness," that is, it must be easy to remove water from the fibrous mat. The mat is typically formed on a Fourdrinier wire, like paper making, or on cylinder formers. Wet process hardboard pressing is done in multi-opening presses heated by steam or hot water. The press cycle consists of 3 phases and lasts 6–15 min. The first phase is at high pressure and removes most of the water while bringing the board to the desired thickness. The second phase is mainly for water vapor removal. The final phase is relatively short and results in the final cure. Maximum pressures used are about 5 MPa. Heat is essential during pressing to induce fiber-to-fiber bond. High temperatures of up to 210°C are used to increase production by faster evaporation of the water. Lack of sufficient moisture removal during pressing adversely affects strength and may result in "spring back" or blistering (Suchsland and Woodson, 1986).

2.2.3.2.3 Hot Pressing

1. Insulation board

For producing soft or insulation board the partially dry wet lap, as it is now called, is trimmed in width and cut into the desire sheet length and dried in tunnel kilns, continuous multi deck. Roller type dryers or hot press with stops at a temperature of 120^0c to 190^0c.

2. Hard board

For the production of hard board single or multiple day light presses heated by stream or hot water are used. The temperature of 120^0c with a high initial pressure of 50kp/cm, followed by a lower pressure of about one fifth of the initial pressure, then bringing the pressure up to the original level with a time schedule of 2/1/3 minutes in typical for a 3.2 mm thick wet process hard board. In these wet process hard board, a screen is used between the mat and the bottom platens of a day light to prevent blowing up of the wet board, so that steam may escape during the low pressure breathing part of the pressing cycle. These boards have one side smooth (Salehuddin, 1992).

2.2.4 Post Treatments of Wet and Dry Process Hardboards

Several treatments exist to increase dimensional stability and mechanical performance of hardboard. They are heat treatment, tempering and humidification and may be done singularly, or in conjunction with each other.

2.2.4.1 Heat treatment

Heat treatment is the exposure of the pressed fiberboards to dry heat that improves the dimensional stability and mechanical properties of the boards. The process also reduces water adsorption and improves the bond between fibers.

2.2.4.2 Tempering

Tempering is the heat treatment of pressed boards, preceded by the addition of oil. Tempering improved the board's surface hardness and is often done on various types of wet-formed hardboard. It also further improves resistance to abrasion, scratching, scarring, and improves the resistance to water. The most common oils used include linseed oil, Tung oil, and tall oil.

2.2.4.3 Humidification

Humidification is the addition of water to bring the board moisture content into equilibrium of the air. Initially, a pressed board has almost no moisture content. When it is exposed to air, it expands linearly by taking on 3–7% moisture. The most common humidifiers for this purpose are the continuous or progressive type. Air of high humidity is forced through the stacks where it provides water vapor to the boards. The entire process is controlled by a dry bulb/wet bulb controller. Other methods include spraying water on the back side of board and the application of vacuum to force the moist air through the board.

2.2.4.4 Fiberboard Finishing

1. Trimming

Consists of reducing the products into standard sizes and shapes. Generally, double-saw trimmers are used to saw the boards. Trimmers consist of overhead mounted saws or movable saw drives. The trimmed boards are stacked in piles for future processing.

2. Sanding

If thickness tolerance is critical, the hardboard is sanded prior to finishing. Sanding reduces thickness variation and improves surface paintability. In sanding, single head, wide belt sanders are used, with abrasive grits varying from 24–36.

3. Finishing

Finishing involves surface treatments to give the board a good appearance and improve performance. The boards are cleaned using water sprays followed by drying at about 240°C for 30 sec. The board's surfaces are then modified using paper overlay, paints, stains, or prints.

2.2.5 Uses of fiberboard

There are different uses of fiberboards. The uses of fiberboard are many and diverse. Fiberboard is the grainless wood of many uses and can be used whenever a dense, hard panel material in the thickness as manufactured will satisfy a need better or more economically than any other material.

1. Furniture Industry

It is used for construction, furniture and furnishings cabinet and store fixture work, appliances and automotive rolling stock. More expensive furniture will generally be constructed out of medium-density fiberboard and, in rare occasions, high-density fiberboard. This type of wood is easily produced, is economical and easy to work with. The cost of prefabricated furniture will vary depending on the materials used. Cost is often supplemented by using low-density fiberboard.

2. Home Interior

Installing cabinets can cost a small fortune but they are a necessity that cannot be avoided. The framework of the cabinet is often made out of fiberboard and then a solid wood face is installed on top of it. This helps to keep costs down and still provide a nice finished product. Fiberboard is used in all aspects of the home interior. Along with cabinets you will find shelving units made from fiberboard as well as doors, molding and even floors. The fact that material is very smooth and takes paint well is also a factor in it being used for doors and cabinets.

3. Home Exterior

The versatility of fiberboard stands out around the home both inside and outside. Fiberboard is often used as a roofing material for a low-slope roof. Fiberboard is a great material to be used as a backing to shingles for any kind of roof. It also is being used as sheathing for walls in the home. It is durable and flexible which makes it ideal for these uses.

4. Vapor Barrier and Insulation

Fiberboard, due to its durability and treatment, makes for a great vapor barrier in conjunction with other vapor barrier products. The wood is able to endure long periods of moisture as well as drying out without deforming or rotting. Besides acting as a vapor barrier it also insulates against heat loss.

5. Soundproofing and Sound Deadening

If you've ever taken apart a speaker you will notice that they are actually constructed out of medium-density fiberboard or particle board. This is because the wood fibers absorb sound which prevents vibration from within the speaker cabinet. This quality makes fiberboard a useful addition to a media room as walls and floor underlayment.

6. Painting

This type of material is commonly used by painters across the world. By covering up the hardboard with a canvas, we can get a very sturdy surface on which to paint. Since it is very inexpensive, painters can buy several pieces of it in order to make multiple canvases.

2.3 Detail Information of Hetal *(Phoenix paludosa)*

2.3.1 Scientific classification

Kingdom: Plantae

Phylum: Tracheophyta

Class: Liliopsida

Order: Arecales

Family: Palmae

Genus: Phoenix

Species: *Phoenix paludosa* Roxb

Species Authority: Roxb

(IUCN Red List, 2011)

2.3.2 General Description

Hetal *(Phoenix paludosa)* is also called Mangrove Date Palm. It is a species of flowering plant in the palm family, indigenous to coastal regions of India, Bangladesh, Myanmar, Thailand, Cambodia, Sumatra, Vietnam and peninsular Malaysia.

They are also known as Sea Dates. The trees grow in clusters, to 5 m high, usually forming dense thickets. The leaves are 2 to 3 m long and recurved.

Fig 2.3: Hetal *(Phoenix paludosa)* stands

2.3.3 Habitat and Ecology

This is a back mangroves species. Individuals often occur in scattered stands of other mangrove species. This species can also form stands of its own in some areas.

2.3.4 Germination of Hantal (Phoenix paludosa Roxb.) seeds

Seeds of P. paludosa, an important palm species of mangrove, ripen in July –August. A brown color of the seeds indicates maturation. Seeds are collected by cutting the bunch.

Fig 2.4: Hetal *(Phoenix paludosa)* seeds

Seeds detach from bunch when storing the bunch in a heap for 2 to 3 days. It takes about 4 to 5 days for decay of the mesocarp. The seeds are then washed and sown in the nursery beds. One kilogram contains about 1200 to 1500 seeds. Seeds may be stored with watering for 60 days. Germination starts from 10 weeks after sowing and continues for up to 20 weeks.

2.3.5 Threats

This species is patchily distributed within its relatively restricted range. Intensive coastal development and extraction of mangroves resources is occurring throughout its range. It is a back mangrove species, and is therefore particularly vulnerable to coastal development and sea-level rise. Mangrove species with a habitat on the landward margin may be particularly vulnerable to sea-level rise if owing to coastal development their movement inland is blocked. Although local estimates are uncertain due to differing legislative definitions of what is a 'mangrove' and to the imprecision in determining mangrove area, current consensus estimates of mangrove loss in the last quarter-century report an approximately 24% decline in mangrove areas in countries within this species range since 1980 (FAO 2007).

All mangrove ecosystems occur within mean sea level and high tidal elevations, and have distinct species zonation that is controlled by the elevation of the substrate relative to mean sea level. This is because of associated variation in frequency of elevation, salinity and wave action (Duke et al. 1998). With rise in sea-level, the habitat requirements of each species will be disrupted, and species zones will suffer mortality at their present locations and re-establish at higher elevations in areas that were previously landward zones (Ellison 2005). If sea-level rise is a continued trend over this century, then there will be continued mortality and re-establishment of species zones. However, species that are easily dispersed and fast growing/fast producing will cope better than those which are slower growing and slower to reproduce.

In addition, mangrove area is declining globally due to a number of localized threats. The main threat is habitat destruction and removal of mangrove areas. Reasons for removal include cleared for shrimp farms, agriculture, fish ponds, rice production and salt pans, and for the development of urban and industrial areas, road construction, coconut plantations, ports, airports, and tourist resorts. Other threats include pollution from sewage effluents, solid wastes, siltation, oil, and agricultural and urban runoff. Climate change is also thought to be a threat, particularly at the edges of a species range. Natural threats include cyclones, hurricane and tsunamis.

2.3.6 Use and Trade

This species is harvested for flooring in households, and construction. People also eat the young shoots.

Chapter Three

Materials and Methods

3.1 Materials and Equipment

3.1.1 Hot Press

A digital hydraulic hot press was used to press the mat into fiberboard. It has multi-layer plate. The both platen were movable up and down. Maximum temperature range within 400°C and pressure up to 4MPa commonly occur.

3.1.2 Hydraulic Universal Testing Machine (UTM)

An analogue hydraulic Universal Testing Machine (UTM), model: WE-100, made by Time group Inc. was used to determine the mechanical properties of the fiberboards. There were two units of this machine, one was control unit and another was working unit. A meter was attached with the control unit for measuring the load (KN). And a scale (mm) was attached with the working unit to measure the deflection. The length of the span, on which the samples were laid, was 248 mm. Another part of the working unit was used to determine the tensile strength, which works vertically.

3.1.3 Oven

A lab scale ventilated oven (Name: Gallennkamp, Size 1, made in UK) was used to determine the moisture content (%) of raw materials as well as the fiberboards. A digital indicator outside the oven indicated the inside temperature.

3.1.4 Moisture Meter

An analogue moisture meter (Model: RC-1E, made by Delmhorst Instrument Co., USA) was used to measure the moisture content of particles.

3.1.5 Electric Balance

An air tight digital balance (Model: AB 204, made in Switzerland) was used to measure the weight of the raw materials as well as fiberboards.

3.2 Manufacturing process of fiberboard

3.2.1 Collection of raw materials

Hetal *(Phonix paludosa)* wood was collected from riverside villages of Koyra, Khulna.

3.2.2 Preparation of raw material

After collecting of raw materials it was kept in air drying condition for several days. Then it was cut into small chips approximately 1 inch in length by the circular saw in wood lab, Forestry and Wood Technology Discipline, Khulna University, Khulna.

Fig 3.1: Hetal wood and Hetal wood chips.

3.2.3 Fiber preparation

Fiber was prepared by two different operations. Such as

A. Grinding
B. Boiling

A. Grinding

The wood chips were grinded by a laboratory grinder. It was done for separation of fiber. It helps to increase the surface area of fibers. After grinding, the coarse and fine particles were separated by screening.

Fig 3.2: Grinder and grinding fiber

B. Boiling

After screening the coarse particles, it was taken to submerge in water for 5 days without any chemical. Then it was subjected to manual beating by traditional hammer. After beating these were boiled into water for 6 hours. Then the fibers were sorted to remove the un- fibrated strips manually. After that the fiber were kept in air drying condition for 2 days.

Fig 3.3: Boiling and boiled fiber

3.2.4 Mat Formation

Fibers were formed into mat on a steel sheet. The mat was formed manually. The thickness of the mat was 30mm and the thickness of the target board was 5mm. Hence, the thickness of the mat was approximately 6 times higher than the target thickness of the board. The size of the mat was seven inch in length and five inch in width.

Fig 3.4: Mat of Hetal fibers.

3.2.5 Hot Pressing

After mat formation, a steel sheet was placed on to the mat and then inserted manually into the hot press for pressing. After inserting the mat into the hot press, the pressure was raised manually by hydraulic jack. Then the electric coil was switched on. The temperature was raised to a maximum of about 170^0 c. then the electric coil was switched off after 12 minutes. Then the fiberboard was retained under 4 MPa pressure for another 20 minutes when the switch was off. So the total pressing time was 32 minutes.

Fig 3.5: Hot Press Machine and hot pressed board.

3.2.6 Trimming

After the preparation of fiberboards, these were trimmed at edges with the fixed type circular saw.

3.2.7 Manufacturing process of Hetal Binderless Fiberboards

Fig 3.6: Hetal Binderless Fiberboard (Grinding)

Fig 3.7: Hetal Binderless Fiberboard (Boiling)

3.3 Laboratory Tests

The laboratory tests for characterization of physical properties and mechanical properties for each type of particleboards were carried out respectively in the Wood Technology Laboratory of Forestry and Wood Technology Discipline of Khulna University and in the Laboratory of Civil Engineering Department of Khulna University of Engineering and Technology, Khulna, Bangladesh.

3.4 Determination of physical properties

All the samples are cut into (50 mm x 35 mm) dimension for testing physical properties. The laboratory test for characterization of physical properties is carried out in the laboratory of Forestry and Wood Technology Discipline, Khulna University, Bangladesh. At first all the specimens are weighted and green dimension are taken at room temperature. Then all the samples are kept into oven for 24 hours. After drying oven dry weight and dry dimension are also measured. Next, the samples are soaked into water for 24 hour. Finally, the wet dimensions are taken and all the physical properties are calculated by using following formula.

3.4.1 Density

Density of each sample was measured in the Wood Technology Laboratory of Forestry and Wood Technology Discipline of Khulna University, Khulna. Density was calculated with the following formula-

$$\rho = \frac{m}{v}$$ (Desch and Dinwoodie, 1996).

Where, ρ = Density in gm/cm^3; m = Mass of the sample in gm and v = Volume in cm^3.

3.4.2 Moisture Content

The moisture content was determined, from the differences in weights before and after the sample has been drying in the oven. Initial and final weight of the samples was measured by electric balance. It was calculated by the following formula-

$$MC\,(\%) = \frac{m_{int} - m_{od}}{m_{od}} \times 100$$ (Desch and Dinwoodie, 1996)

Where, MC = Moisture content (%)

m_{int} = Initial mass of the sample (gm)

m_{od} = Oven-dry mass of the sample (gm).

3.4.3 Water Absorption

Water absorption is defined as the difference in weight before and after immersion in water and expressed in percentage. The water absorption was calculated by the following formula-

$$A_w = \frac{m_2 - m_1}{m_1} \times 100$$ (ASTM, 1997)

Where,

A_w = Water absorption (%),

m_2 = the weight of the sample after (24 hr.) immersion in water (gm),

m_1 = the weight of the sample before immersion in water (gm.).

3.4.4 Thickness Swelling

Thickness swelling was calculated by the following formula-

$$G_t = \frac{t_2 - t_1}{t_1} \times 100$$ (ASTM, 1997)

Where,

G_t = Thickness swelling (%),

t_2 = Thickness of sample after immersion (24 hr.) in water (mm),

t_1 = Thickness of sample before immersion in water (mm).

3.4.5 Linear Expansion

The Linear Expansion was calculated by the following formula-

$$LX(\%) = \frac{L_A - L_B}{L_B} \times 100 \qquad \text{(ASTM, 1997)}$$

Where,

L_A = Length of sample after immersion (24 hr.) in water (mm),

L_B = Length of sample before immersion in water (mm).

3.5 Determination of Mechanical Properties

All the samples are cut into required dimension for testing mechanical properties. The laboratory test for characterization of mechanical properties is carried out in the laboratory of Civil Engineering Department of Khulna University of Engineering and Technology, Khulna, Bangladesh.

3.5.1 Modulus of Rupture (MOR)

Modulus of rupture (MOR) was measured with the Universal Testing Machine (UTM), model: WE-100, made by Time Group Inc. in the Laboratory of Civil Engineering Department of Khulna University of Engineering & Technology, Khulna.

The MOR was calculated from the following equation-

$$MOR = \frac{3PL}{2bd^2} \qquad \text{(Desch and Dinwoodie, 1996)}$$

Where,

MOR = the modulus of rupture in (N/mm2),

P= Load in N, L= Span length in (mm),

b= width of test sample in (mm),

d= Thickness of test sample in (mm).

3.5.2 Modulus of Elasticity (MOE)

The Modulus of elasticity (MOE) was also measured with the Universal Testing Machine (UTM) in the Laboratory of Civil Engineering Department of Khulna University of Engineering & Technology, Khulna. The modulus of elasticity (MOE) was calculated from the following equation-

$$MOE = \frac{P'L^3}{4\Delta bd^3}$$ (Desch and Dinwoodie, 1996)

Where, MOE is the modulus of elasticity in (N/mm2), P′ is the load in N at the limit of proportionality, L is the span length in (mm), Δ is the deflection in mm at the limit of proportionality, b is the width of sample in (mm), d is the thickness/depth of sample in (mm).

Analysis of Data

All data, produced during the laboratory tests for characterization of physical and mechanical properties of fiberboards, was analyzed by using Microsoft Office Excel 2010 and Minitab software.

Chapter Four

Results and Discussion

4.1 Physical Properties

4.1.1 Density

Density is an important indicator of fiberboard performance and it strongly affects all the properties of fiberboard. It depends on the density of raw materials used, treatments of raw materials, hot pressing condition and other factors. In this study the density of binderless Hetal fiberboards were found 0.78 g/cm^3 and 0.72 g/cm^3 from non-treated fiber (grinding) and treated fiber (boiling) respectively (Fig 4.1). The density of medium density fiberboard was 0.75 g/cm^3 (ANSI A208.1-1993).

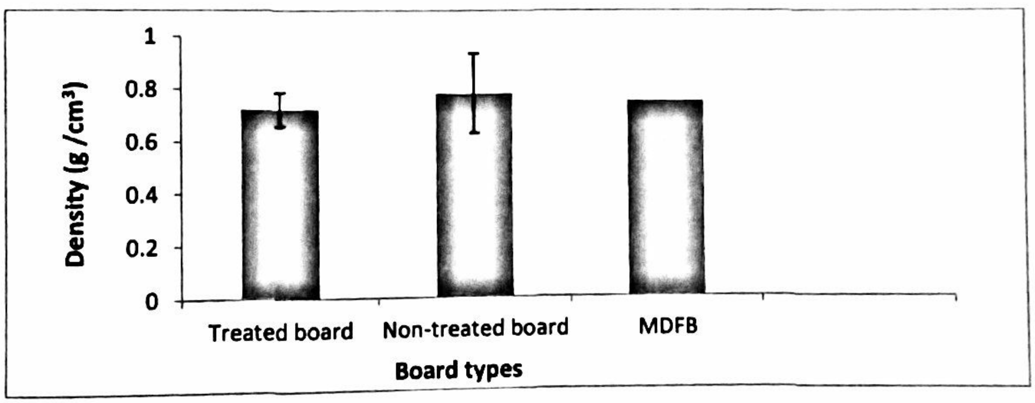

Fig 4.1: Density of Hetal Binderless Fiberboards (Treated and Non-treated Boards) and Medium Density Fiberboard (MDFB).

It was found that the density of binderless Hetal fiberboard with grinded fibers was higher than the medium density fiberboard but board with boiling treated fibers showed lower density (4.1). The variation may be due to the variation in density of raw materials itself. Pressing temperature, hot pressing condition and other factors affect on board density (Sekino, 1999; Volasqueze et al., 2003). Density also depends on the proper distribution of lignin between the particles during pressing process (Arias, 2008).

4.1.2 Moisture content

The moisture content ensures good physical and mechanical properties and dimensional stability. The moisture content of binderless Hetal fiberboards with treated fibers (Boiling) and non-treated fibers (Grinding) were found 11.73% and 8.88% respectively (Fig 4.2). The moisture content of Medium Density Fiberboard (MDFB) was 9% (ANSI A208.1-1993).

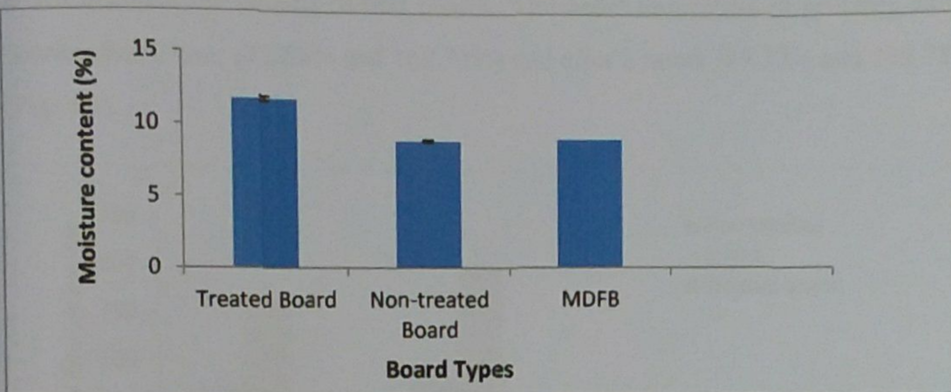

Fig 4.2: Moisture content of Hetal Binderless Fiberboards (Treated and Non-treated Boards) and Medium Density Fiberboard (MDFB).

From the figure (Fig. 4.2) we can see that the treated fiberboard contains higher moisture content and non-treated fiberboard contains lower moisture content than the Medium Density Fiberboard (MDFB). The variation of moisture content within these types of boards may be due to the variation in moisture content of raw materials itself or other parameters like chemical behavior of the particles or variation of temperature during pressing time. Temperature has direct impact on moisture content as temperature is related to melting of lignin. If the board is produced by higher temperature, it absorbs less moisture content (Mancera et al., 2011)

4.1.3 Water Absorption

For binderless boards the water absorption is an important property. Water absorption should be less for better performance of binderless boards. Water absorption of the manufactured boards was measured in two times, after 1 hour and after 2 hours from the time of sample immersion into water. The figure (Fig. 4.3) showed that the boards made with grinding fibers were absorbed less water than the boiling treated boards. The water absorption of grinding and boiling treated boards after 1 hour (72.68% and 162.35%) and after 2 hours (85.37% and 195.78%) respectively (Fig. 4.3).

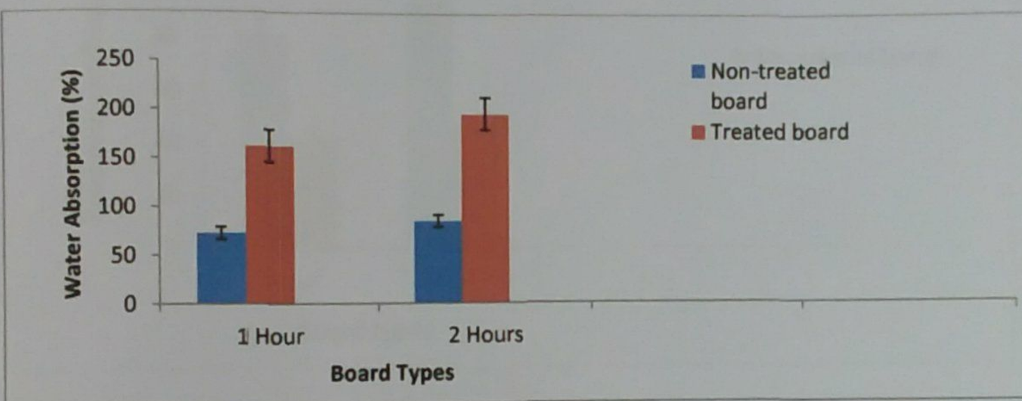

Fig 4.3: Water absorption of Hetal Binderless Fiberboards (Treated and Non-treated Boards).

Binderless board made with spruce and pine showed water absorption 45% and 75% (Angles et al., 1999). In the study we found (Fig. 4.3) that the water absorption capacity of Hetal binderless fiberboard was comparatively higher. This variation may be due to the presence of hydroxyl and other polar groups in various constituents of raw materials (Basak et al., 1998).

But fiberboard with boiling treated fibers showed higher water absorption percentages than the non-treated (grinding) board because of low density. Water absorption is related to density of the boards. Higher density board contains less porosity and high compactness than the lower density board (Tangjuank, 2011).

4.1.4 Thickness Swelling

Thickness swelling is related to the dimensional stability of the boards. This property gives us an idea how the boards will behave when used under conditions of severe humidity and are especially important regarding boards that are to be used externally (Mancera et al., 2011). The thickness swelling of grinding and boiling treated boards after 1 hour (42.65% and 81.39%) and after 2 hours (48.37% and 95.78%) respectively (Fig. 4.4).

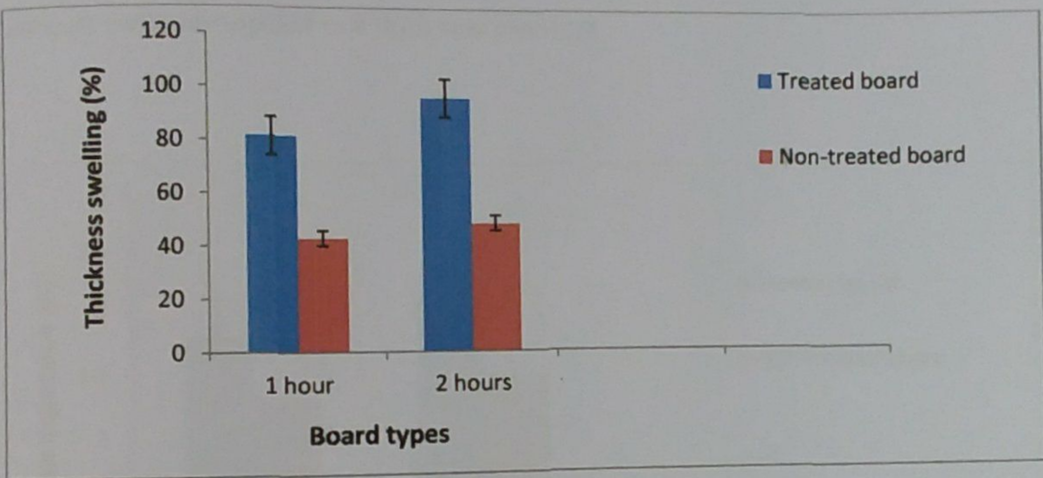

Fig 4.4: Thickness swelling of Hetal Binderless Fiberboards (Treated and Non-treated Boards).

Thickness swelling varies between 5.8% and 14.7% in the case of particleboard (JIS A 5908). In the case of medium density fiberboard thickness swelling of the board was 8% (ANSI A208.1-1993). Binderless boards made from spruce and pine showed thickness swelling 12% and 37% (Angles et al., 1999). So, thickness swelling of Hetal binderless fiberboard was comparatively higher than other boards. The factors affecting water absorption are responsible for the thickness swelling of the boards. From the figure (Fig. 4.4) we can see that non-treated board (grinding) showed lower thickness swelling than the treated (boiliong) board. This variation may be due to presence of residual lignin which acts as a strong binder. Moreover, thickness swelling largely depends on water absorption and density of the boards (Rahman et al., 2013). This may another cause for lower thickness swelling of non-treated (grinding) Hetal fiberboards.

4.1.5 Linear Expansion

Linear expansion is another indicator for better performance of binderless boards. When the linear expansion is less, it will show better physical properties. The value of linear expansion of grinding and boiling treated Hetal binderless fiberboard after 1 hour (1.26% and 1.79) and after 2 hours (1.47 and 2.38) respectively (Fig. 4.5).

Fiberboard with boiling treated fibers showed higher linear expansion. This variation may be the same as water absorption and thickness swelling.

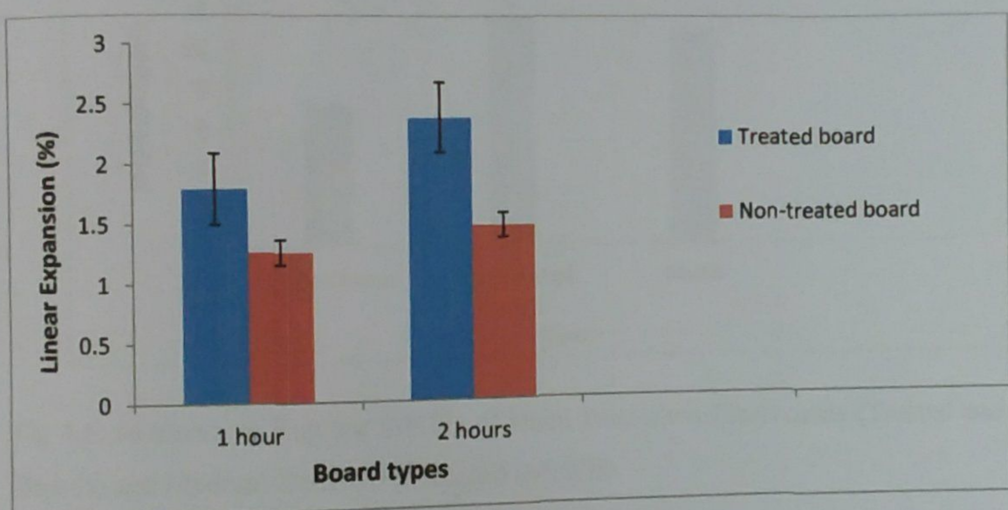

Fig 4.5: Linear expansion of Hetal Binderless Fiberboards (Treated and Non-treated Boards).

4.2 Mechanical Properties

4.2.1 Modulus of Rupture (MOR)

Mechanical properties of any board depend on density. The non-treated board (grinding) contains higher density than the treated board (boiling). The measured Modulus of Rapture (MOR) of grinded Hetal binderless fiberboard was 11.75 N/mm^2 and fiberboard with boiling fibers showed MOR of 7.20 N/mm^2. The MOR of Medium Density Fiberboard (MDFB) was found of 11 N/mm^2 (ANSI A208.1-1993).

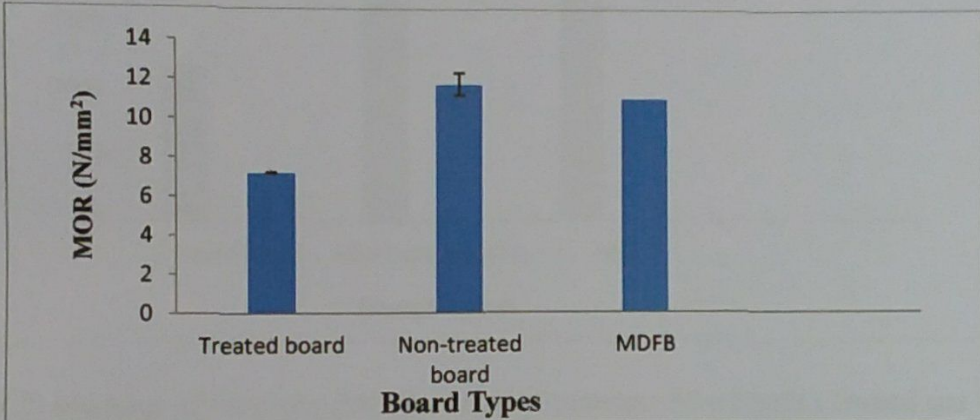

Fig 4.6: Modulus of Rupture (MOR) of Hetal Binderless Fiberboards (Treated and Non-treated Boards) and Medium Density Fiberboard (MDFB).

From the figure (Fig. 4.6) we can see that only the non-treated (Grinding) fiberboard satisfy the required MOR of Medium Density Fiberboard (MDFB). On the otherhand, boiling treated fiberboard showed very poor MOR. This variation may be due to the variation of stem pressure. The MOR of the binderless boards is also affected by moisture content present in the particles (Widyorini et al, 2011). The nature and the extent of natural bonding are the important parameters affect the mechanical properties. The residual lignin acts as a natural adhesive in binderless fiberboards (Widyorini et al, 2005). During boiling treatment the residual lignin is partially removed. So the non-treated (grinding) board showed better MOR than the boiling treated board.

4.2.2 Modulus of Elasticity (MOE)

The modulus of elasticity (MOE) of grinded and boiling fiberboard was found 1695 N/mm^2 and 1170N/mm^2 respectively (Fig 4.7).The MOE of Medium Density Fiberboard (MDFB) was found 1725N/mm^2 (ANSI A208.1-1993). From the figure (Fig. 4.7) it is found that the MOE of non-treated (grindig) Hetal binderless fiberboard was close to the MOE of medium density fiberboard (MDFB). But fiberboard made from boiling treated fibers showed very poor MOE.

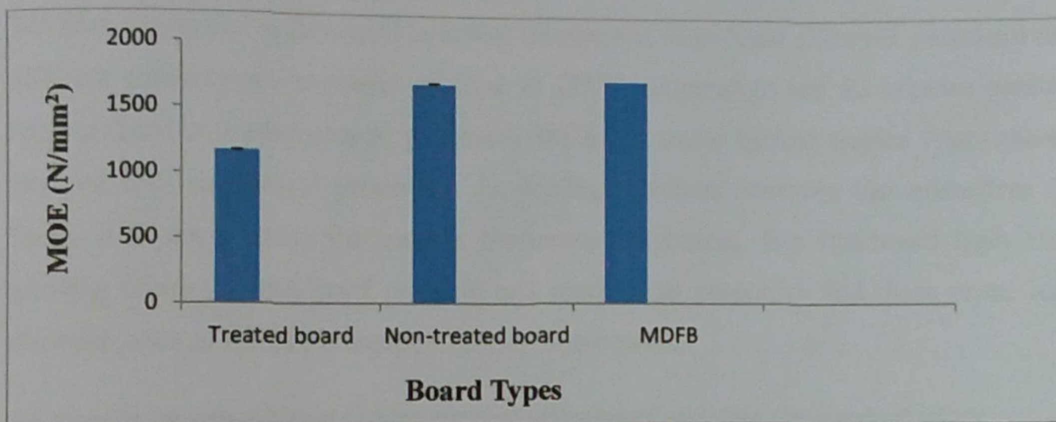

Fig 4.7: Modulus of Elasticity (MOE) of Hetal Binderless Fiberboards (Treated and Non-treated Boards) and Medium Density Fiberboard (MDFB).

The explanation of these results is similar to the MOR. According to Khedari el at, (2003) the more binding and fibrous materials give better mechanical properties. In grinding treatment bagasse turned in more fibrous form and it also contained the residual lignin which act as a good binder and it is the suspected reason of the MOE variation of two treatments. The MOE of non-treated (grinding) Hetal binderless fiberboard satisfy the ANSI standard of medium density fiberboards.

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Chapter Five

Conclusion

Conclusion

We have succeeded to develop binderless fiberboards from Hetal *(Phoenix paludosa)* under two different pretreatment processes of fiber at 170^0C temperature and 12 minutes pressing time. Among these two pretreatment processes, the board under boiling treated fibers showed poor physical and mechanical properties. As boiling treatment removed the extractives from the fibers, it is not suitable for making binderless fiberboards. But fiberboard from Hetal with grinding fibers showed good physical and mechanical properties and these result satisfy the standard value of ANSI for medium density fiberboards.

As a whole we can say that binderless Hetal fiberboard satisfied the standard result.

So, according to the findings of the work, Hetal has the feasibility to becoming the potential source of raw material for fiberboard manufacturing industries in the current context of raw material crisis.

Further study can be done to improve the board qualities by using different parameters.

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