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UTILIZATION OF JIBON TREE (*Trema orientalis*, Linn. Blume) AS A RAW MATERIAL FOR MANUFACTURING OF PARTICALBOARD

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STUDENT ID: 140540

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PARTHO PROTIM DAS

STUDENT ID: 140540

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Declaration

I, Partho Protim Das, declare that this is the result of my own work and it has not been submitted to or accepted for any degree in any other University.

I, hereby, give consent for my thesis, if accepted, to be available for photocopying and for inter-library loans, and for the title and summary to available to outside organizations only for research and educational purposes.

(Partho Protim Das)

Dedicated

To

My Beloved Family

APPROVAL

This project thesis has been submitted to Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh, in Partial fulfilment of Four Years professional B. Sc. (Hon's.) degree in Forestry. I approve the Style and format of the project thesis.

Supervisor

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Partho Protim Das

Abstract

This thesis paper represents the physical and mechanical properties of Jibon trees (*Trema Orientalis,Linn.* Blume) Particleboard. The particleboard made from *Trema orientalis* with different ratio of adhesive (Urea Formaldehyde) show different qualities. Some of them show satisfactory properties. The Modulus of Elasticity (MOE) and the Modulus of Rupture (MOR) made from *Trema Orientalis* satisfy some world standard Value. Such as particleboard with 20% adhesive MOE and MOR value are 3311.64 N/mm^2 and 23.64 N/mm^2 respectively which are very good. But these particleboard exhibits higher density (878.69Kg/m^3) and thickness swelling (37.41%) than standard level. Its moisture content is 4.25%, which is lower than the standard level.

Table of Contents

List of Contents **Page no.**

List of Tables

List of Figures

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Wood is one of the most important materials for construction purpose. But as our forest are limited and decreasing gradually for the extensive extraction of wood. So the use of composite wood is increasing day by days such as particleboard, plywood, hardboard, oriented standard board, medium density fibreboard and veneer board. Among them the demand of particleboard has been increasing significantly because of construction, interior decorator, manufacturing of furniture, flooring, stair, cabinet, laboratories and other industrial product. This huge demand of particleboard accelerates the extraction of forest resources. Thus the demand of alternative sources of raw material is increasing ever more. In our countries only a few species are used as raw material. To reduce the pressure on forest species and fulfil the huge demand it is essential to introduce an alternative species.

Trema orientalis is locally known as Jibon tree. It is very fast growing species. And can be grown on different types of land. In India it is extensively used for charcoal production. *Trema orientalis* good for paper making as its fibre has good flexibility. It is also a suitable species for agroforestry or social forestry. So if this species has good properties for particleboard production, then it can be a good source for particleboard production.

1.2 Objective of the Study

- To introduce an alternative source of raw material for manufacturing particleboard.
- To assess the feasibility of Jibon (*Trema orientalis*) as a raw material for particleboard manufacturing.

CHAPTER TWO: LITERATURE REVIEW

2.1 General Information about Particleboard

2.1.1 Definition of Particleboard

A particleboard is board (or sheet) constituted from fragments of wood and/ or other lingo cellulosic materials (chips, shavings, flakes, splinters, sawdust etc.) bonded with organic binders with or without the help of one or more agents like heat, pressure, humidity, catalyst etc. (Srivastava, 1969). It may be classified as a panel product manufactured under pressure and heat from particles of wood or other lingo-cellulosic materials bonded entirely with a binder, generally a synthetic resin, to which other chemicals (e.g., fire retardant etc.) may be added to improve certain properties (Salehuddin, 1992).

2.1.2 Brief History and Development of Particleboard

Particleboard is not more than a few decades old production. Before particleboard, modern plywood, as an alternative to natural wood, was invented in 19th century, but by the end of the 1940s there was not enough lumber around to manufacture plywood affordably. By that time particle board was intended to be a replacement. But before the scarcity I raw materials of plywood, first efforts were made in the early 1920s for manufacturing of particleboard. It was unsuccessful as for the lack of suitable adhesive. Then new technique introduce in the 1930s in resins applications with the growing demandpaved the way for the industrial production of particleboard in the early 1940s (Moslemi, 1985). The first commercial piece wasproduced during World War II at a factory in Bremon, Germany. It used waste materials such as planer shavings, off-cut of sawdust, hammer –milled into chips and bound together with a phenolic resin. Today's particleboard manufacturer provides high-quality products that consumers require due to up gradation of manufacturing techniques (Anon, 2070 and Moslemi, 1985)

2.1.3 Types of Particleboard

There are different types of particleboards depending on

2.1.3.1 Types of particles used

- Flake board: a particleboard in which the wood largely in the form of flakes, giving the surface a characteristics appearance (Srivastava, 1969).
- Chip board: a particleboard made from chips. It is made in varying thickness and may surface with paper, veneers, plastics materials etc. (Anon, 1970 and Srivastava 1969).
- Shavings board: a particleboard in which wood shavings are chief constituents. (Anon, 1970 and Srivastava 1969).
- Wafer board: it is a structural materials made from rectangular wood flakes of controlled length and thickness bonded together with waterproof phenolic resin under extreme heat and pressure (Anon, 2008[a] and Salehuddin, 1992).
- Oriented strand board: Oriented strand board or OSB (UK) or smart ply (UK and Ireland) is an engineered wood product fromed by layering strands (flakes) of Wood in specific orientations (Salehuddin, 1992).

2.1.3.2 Particle Size Distribution in the Thickness of Board

- Single layer or homogenous board.
- Three layer board, where course particle I the core layer are sandwiched between fine particles in the face layers
- Multi-layer or graduated board, with a graduation of particle ranging from finest in the face layer to coarsest in the core(Salehuddin, 1992).

2.1.3.3 Density of the Particleboard

- Low density particleboard: Density bellow 590 kg/m^3 or 37 lb/ft^3 ,
- Medium density particleboard: Density ranges from 590 to 800 kg/m^3 or 37 to 50 lb/ft^3 and
- High density particleboard: Density represents above 800 kg/m^3 or 50 lb/ft^3 (Sirvastava, 1969).

2.1.3.4 Exposure or Service Condition

- Particleboard for indoor use: Where exposure to water or high humidity does not occur and
- Particleboard for exterior use: where exposure to environmental condition occur. Exterior particleboards may be further classified into
    - Structural and
    - Non structural boards (Salehuddin, 1992).

2.1.4 Raw Materials for Particleboard Manufacturing

2.1.4.1 Lingo-Cellulosic Materials

2.1.4.1.1 Woody Materials

- Planer savings
- Sawmills residues, such as slabs, edging, trimming etc.
- Residues from cutting of timber In furniture and cabinet manufacturing plants.
- Residues from match factories (Kadam, Cahtian).
- Veneer and plywood plant residues, such as short logs, broken logs, small tree tops and branches, forests thinnings etc.
- Bark.

2.1.4.1.2 Non-Woody Materials

- Jute sticks.
- Bagasse.
- Bamboo.
- Flax shaves.
- Cotton stalks.
- Almost any agricultural residues (such as husks, coconut coir etc.)after treatment (Youngquist, 1999).

2.1.4.2 Chemicals

2.1.4.2.1 Binder or Adhesive

Adhesives or binder are the materials used in the fabrication of timber structures and components offer a meat and efficient method of bonding together the separate pieces of wood, or of board products such as ply wood, chipboard or fibreboard which comprise the finished product. ASTM (1997) defines an adhesive as a substance capable of holding materials together by surface attachment. The bond attained must meet the strength requirements fer the structure as a whole and this bond must remain unaffected by the condition to which it will be exposed throughout its life (Yougquist, 1999).

2.1.4.2.1.1Types of Adhesive/Binder

There are mainly two types of adhesive. One originated from natural source known as natural and another is synthetic adhesive.

- **Natural adhesive**: Adhesive of natural origin- such as animal, casein, soybean, starch and blood glue are still being used to bond wood in some plants and shops, but are being replaced by synthetics (Vick, 1999).
- **Synthetic adhesive or synthetic resin adhesive**: synthetic adhesive are man-made polymers which resemble natural resins in physical characteristics but which can be tailored to meet specific woodworking requirements. Synthetic adhesive can be categorized into two group, namely thermosetting adhesives and thermoplastic adhesives (Natasaet el. 2011).

2.1.5 Variables Affected the Quality of Particleboard

- Particle geometry and slenderness ratio (s): The main aspect of particle geometry is the slenderness ratio range of 120 to 200 seems best (Salehuddin, 1992)

- Raw materials and compression ratio: Particleboard must be compressed during hot pressing from 5% to 50%. Lower-density raw materials have greater compression ratio. So higher modulus of rupture, modulus of elasticity internal bond and tensile strength properties are achieved (Salehuddin, 1992).
- Birder mixing properties and mixing: Generally adhesive mixing proportion for particleboard is different for different types of adhesive. Based on ratio of wood flour and binder WPC board property will vary (Anon, 2006).
- Pressing time, temperature, pressure etc. are also affecting the quality of particleboard.

2.2 Uses of Particleboard

Particleboards are used as:

- Shelves
- Table top
- Cabinets
- Wall cases
- Benches
- Book cases
- Kitchen cabinets
- Piano and organ parts
- Flush-door cores
- Mobile homes
- Floor underlayment, etc.

2.3 Advantages of Particleboard

- Particleboards overcome some inherent weakness of solid wood and make useful products out of wastes, small pieces of wood and inferior species thus ensuring complete utilization of raw material, make products with unique properties can tailor products for particular end-use.

- The characteristics defects of wood such as knots spiral grain etc. may either be eliminated or scattered throughout the particleboard during manufacturing. Thus ensure not occurring defects during service condition.
- The variation in strength stiffness due to anisotropy in wood is largely overcome as also the differential changes in dimension due to absorption and desorption of moisture along or across the grain of wood.
- During the manufacture of particleboard, various treatments such as heating incorporation of chemical additives, etc. may be carried out to improve many physical and mechanical properties including the dimensional stability.
- By using different species and adhesive, or particles of different size and geometry, particleboard may be manufactured suitable for exposure to weather for interior use, for interior panelling, for exterior sideboards, for load bearing flooring purpose and so on.
- Perhaps the most important advantage of particleboard is that it can be made in large dimension (Salehuddin, 1992)

2.4 Consideration for the Quality of Particleboard

- Geometry of the particles i.e. length, width, thickness, diameter etc.
- Species from which the raw materials are collected.
- Slenderness ratio(s), i.e. the ratio of length (l) over thickness (t) of particles with square of rectangular of cross section, s=1/d, is a highly important parameter. For the majority of properties, long thin chips, with a slenderness ratio of 120 to 200 seem best. However, surface quality and internal bond strength are higher with small particles, i.e. with lower slenderness ratio (salehuddin, 1992).

2.5 General information about Jibon (*Tremaorientalis*)

2.5.1 General Information

English Name: Charcoal Tree.

Common Names: India Charcoal Tree, Pigeon Wood, Oriental trema (Grain, 2007), Gunpowder Tree (Little Jr., Elbert L.; Skolmen, Roger G. 1989)

Botanical Nome: Trema orientalis(L.) (Blume, 1852)

Family: Cannabaceae

Distribution Range: Indian subcontinent, Southern China, Japan, Myanmar, Thailand, Vietnam, Malaysia, Indonesia, Tropical Zone of Africa, Australia to the Pacific Islands. (Grain, 2007)

2.5.2 Description

Charcoal tree is a fast-growing, evergreen shrub or tree. It has a heavy branching and rounded to spreading crown, reaching a height of up to 18 metres (World Agroforestry Centre). It has a short basally swollen bole that can be 60cm in diameter. Its bark is smooth and light grey with conspicuous lenticels. The leaves are simple, alternate and stipulate. Flowers are small, inconspicuous and greenish. They are usually unisexual. Flowers appear irregularly from late winter to autumn. (wikipedia), (Useful Tropical Plant), (SANBI)

2.5.3 Uses

General Use: The wood is relatively soft, and burns easily and quickly when dry. The wood is suitable for paper and pulp production (Anthony, 2009), (M.S. *et al.*2007) producing paper with good tensile strength and folding endurance. The bark can be used for making string or rope, and used as waterproofing fishing-lines (Alice, 2005). In India and Tanzania, the wood is used to make charcoal.

Medical Use: The leaves and the bark are used to treat coughs, sore throats, asthma, bronchitis, gonorrhea, yellow fever, toothache, and as an antidote to general poisoning.

2.5.4 Reproduction

Germination rate is around 30%. Viability can be maintained for 6 months in a control condition (World Agroforestry Centre). *Trema orientalis* is a common pioneer tree, seed germinates readily and growth is rapid. It's a good tree to plant in new empty gardens needing a tree to grow quickly. It's a good shade tree or street tree.

CHAPTER THREE: MATERIALS AND METHOD

3.1 Materials and Equipment

3.1.1Chipper

A locally made small lab scale chipper was used to chip the raw materials. The RPM of the chipper's motor was 1420 with six cutter head.

3.1.2 Hot Press

A digital hydraulic hot press was used to press the mat into particleboard. It has multi-layer plate. The both platen were movable up and down. Maximum temperature ranges within 300°C and pressure up to 40Mpa commonly occur.

3.1.3 Hydraulic Universal Testing Machine (UTM)

A digital hydraulic universal testing machine used for test MOR, MOE.It is Shimadzu Autograph AGS-X series made in China. There are two unit of this machine, one is control unit and another is working unit. A digital meter controls the load (KN) and deflection.

3.1.4 Oven

A lab scale ventilation oven (Name: Binder Climate Chabers, Germany) was used to determine the moisture content (%) of raw materials as well as the particleboards.

3.1.5 Moisture Meter

A digital moisture meter is used to measure the moisture of particle and raw materials instantly.

3.1.6 Electric Balance

An air tight balance (Model: AB 204, made in Switzerland) was used to weight of the materials as well as the particleboards and also used to Measure the weight of different ingredients of the adhesive.

3.2 Method and procedures

3.2.1 Collection of Raw Materials

Raw material of Jlbon (Trema orientalis) was collecting from beside Old Satkhira Road, Daulatpur, Khulna for the manufacturing of particleboard. For the purpose of preparing samples the defect free straight boles are collected and then it chipped by chopper machine. After chipping, the wood chips are run into grinder machine, by which the wood turned into wood particle. In this study particle ranges < 1 mm is used.

3.2.2 Selecting Variables

There are two types of variables i.e. dependent and independent. In this study pressure and temperature are dependent variable. Temperature is fixed at 160°C and the Pressure is 5 MPa. According to Nadir et al., (2011), temperature has little effect on mechanical properties of particleboard. Different study show that 5 MPa pressure is better for producing good quality particleboard, on the other hand melting temperature is of Urea Formaldehyde is ranges 130-160°C. So that fixing temperature at 160°C is very reasonable for this study.

Here the adhesive ratio is the independent variables. Within the fixed variable five different ratio 8%, 10%, 15%, 18% and 20% was taken for particleboard manufacturing from *Trema orientalis.*

3.2.3 Manufacturing Place

The particle was manufactured at wood laboratory that is controlled under forestry and wood technology discipline, Khulna University, Khulna. All test were done there.

3.2.4 Manufacturing Procedure

3.2.4.1Preparetion of Raw Material

The stalk was cut into marrow sticks after the narrow sticks were cut into small pieces by circular saw to feed into the chipper. Then the pieces of stalk kept under open sun for 30 days for drying (Salehuddin, 1992; AWPA,2001 and Youngquist, 1999).

3.2.4.2 Particle Preparation

To produce particle of the stalk chipping was done with chipper machine. The small pieces of stalk were inserted separately into chipper machine. The holes in the perforated mesh that was used in the chipper machine were approximately 8 mm in diameter. From the machine the particles were collected manually (Salehuddin, 1992).

3.2.4.3 Drying of Screened Particles

After screening the particles were inserted into the oven for drying. In the oven the temperature was 103°C and after drying the Moisture content was 5.8%. For use with binder the particles must be reduced to about 2% to 7% moisture content (Anon, 2006).

3.2.4.4 Mixing of Binder

The addition of adhesive of Urea Formaldehyde with wood particle is done by handshaking process (Hwang and Hsiung, 2000). It is a critical step for both product quality and production efficiency (Youngquist, 1999). In this study wood particle (WP) and Urea Formaldehyde (UF) were mixed, where adhesive amount is 8%, 10%, 15%, 18% and 20% of wood particle.

3.2.4.5 Mat Forming

After mixing with adhesive, the particles were formed into mat separately on the separate steel sheet. The mats of each type were formed manually by hand. Mat is formed into 3-4 times and even 20 times thicker than the target board thickness, depending on the particle geometry and density of the raw material (Salehuddin, 1992 and Youngquist, 1999).

3.2.4.6 Hot Pressing

After mat formation, a steel sheet was placed on to the mat and then inserted manually into the hot press (each type separately) for pressing. After inserting the mat into the hot press, the pressure was raised manually by digital hydraulic hot press up to 5 MPa. There the total press time was 10 minutes, temperature was 160°C. Hot-press temperatures for thermoplastic materials (e.g. Urea formaldehyde) usually range from 165°C to 190°C. Pressure depends on a number of factors, but it is usually in the range of 1.37 to 3.43 MPa and >3.35 MPa for medium-density and high density boards. Upon entering the hot press, mats usually have a moisture content of 8% to 12%, but this is reduced to about 5% to 9% during pressing. This process of particleboard manufacturing is called flat-press process (AWPA, 2001 and Youngquist, 1999).

3.2.4.7 Conditioning and Finishing

After stopping temperature the board was remained fixed for cooling or conditioning. The heat is removed from the press and further conditioned to equilibrate board moisture content and to stabilize and fully cure the adhesives (AWPA, 2001). After the boards of each type were produced separately, these were trimmed at edges with the fixed type circular saw.The board is trimmed to obtain the desired length and width and to square the edges. Trim losses usually amount to 0.5% to 8%, depending on the size of the board, the process employed, and the control exercised (Youngquist, 1999).

3.2.5 Laboratory Test

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, Khulna. The properties were tested according to the procedures defined in the American standard for particleboards (NPA, 1993) (Anon, 1985).

3.2.5.1 Preparation of Samples for Testing

Three replications of each type of boards were manufactured as stated earlier. For testing physical properties, three samples were collected from each board of each type. So the total number of sample was fifteen (15) for each type of particleboard for testing of physical properties. The Density and Moisture Content were determined on the same fifteen (15) samples and the Water Absorption and Thickness Swelling were determined on the other fifteen (15) samples. For testing mechanical properties, three samples were collected from each board of each type. So the total number of sample was fifteen (15) for each type of particleboard for testing of mechanical properties. The MOR and MOE were determined on the separate samples.

The dimension of samples for testing the physical properties was approximately (50 mm x 50 mm) and for testing the mechanical properties was approximately (180 mm x 50 mm).

3.2.6 Determination of Physical Properties

All the samples are cut into (50 mm x 50 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.

3.2.7 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 Forestry and Wood Technology Discipline., Khulna University, Bangladesh.

3.2.9 Analysis of Data

All the data, produced during the laboratory tests for characterization of physical and mechanical properties of each type of particleboards, were analyzed by using Microsoft Office Excel 2010. ANOVA (Analysis of Variance) was done to analyze the data.

CHAPTER FOUR: RESULT AND DISCUSSION

4.1 Results

After manufacturing particleboard from *Trema Orientalis* different physical and mechanical properties are tested in different laboratory controlled by Forestry and Wood Technology Discipline in Khulna University. Here I made five types of board by altering the amount of adhesive as A (8% adhesive), B (10% adhesive), C (15% adhesive), D (18% adhesive) and E (20% adhesive).The result of tested sample is given below.

Table 4.1: Summary of the result of different physical and mechanical properties.

Properties	Particleboard from *Trema Orientalis* with different amount of adhesive				
	8% (A)	10% (B)	15% (C)	18% (D)	20% (E)
Density (Kg/m^3)	729.69	738.98	792.36	813.60	878.69
Water absorption (%)	165	152.94	86.95	79.41	38.29
Moisture content (%)	12.5	11.76	6.52	8.82	4.25
Thickness Swelling (%)	110.95	92.87	47.54	46.47	37.41
MOE (N/mm^2)	1292.77	1274.5	1211.95	2010.54	3311.64
MOR (N/mm^2)	7.84	8.86	12.30	21.22	23.64

High Density = >.80 gm/cm^3, Medium Density = .64 to 0.80 gm/cm^3 and Low Density = < 0.64 gm/cm^3.

4.2 Discussions

4.2.1Physical properties

4.2.1.1 Density of the board

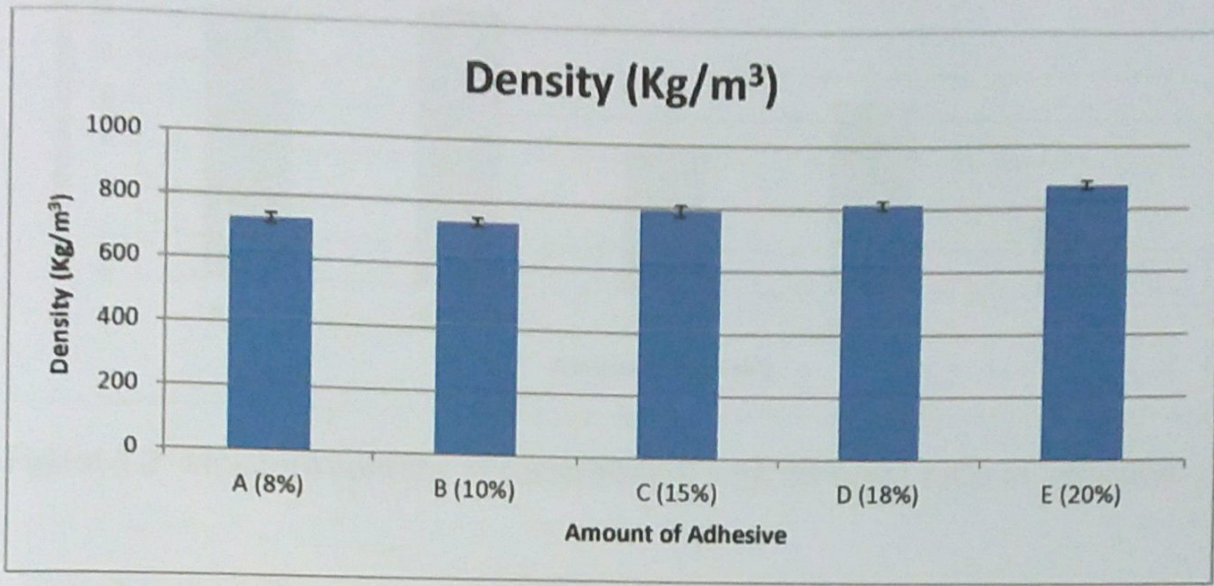

Figure 4.1: Density of particleboard with different ratio of adhesive.

I found that the average density of *Trema Orientalis* particleboard of 8%, 10%, 15%, 18% and 20% adhesive are respectively 729.69 Kg/m^3, 738.98 Kg/m^3, 792.36 Kg/m^3, 813.60 Kg/m^3 and 855.24 Kg/m^3. According to IS specification 3087 (Anon, 1985) the density of standard particleboard is 500-900 Kg/m^3 and according German Standard Din 68761 (Verkor, 1975) particleboard standard is 590-750 Kg/m^3.

4.2.1.2 Moisture content after curing

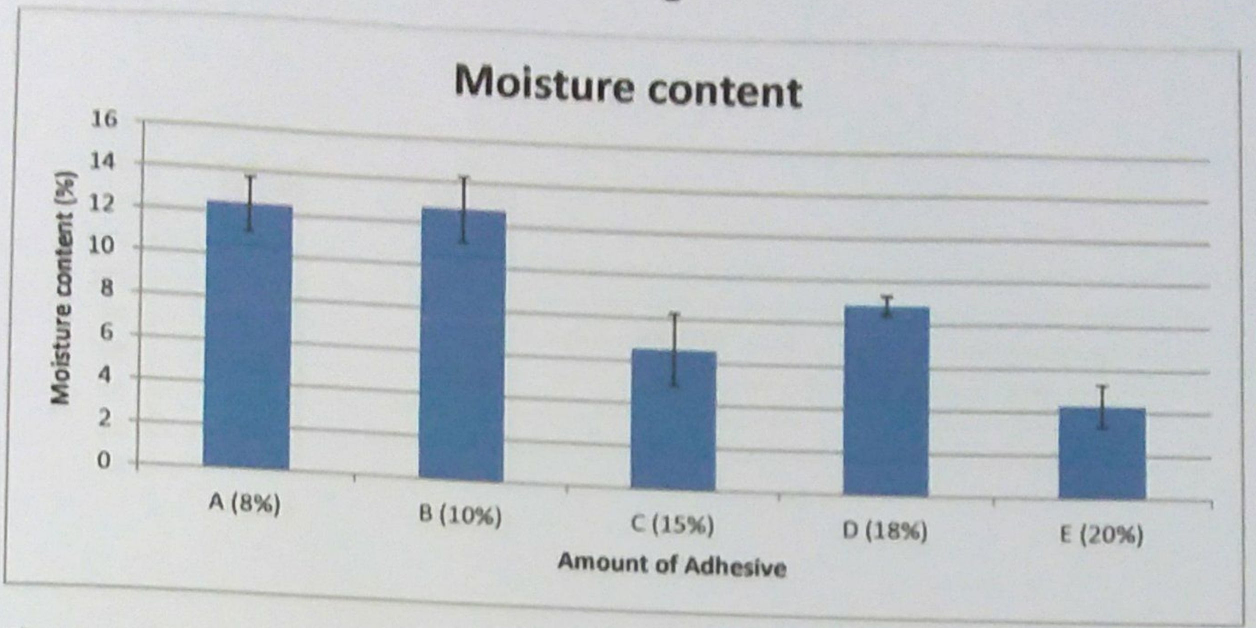

Figure 4.2: Moisture content of particleboard with different ratio of adhesive.

The average Moisture of *Trema Orientalis* particleboard of 8%, 10%, 15%, 18% and 20% adhesive are respectively 12.5%, 11.76%, 6.52%, 8.82%, and 4.25%.The maximum moisture content in the standard particleboard is not found as per ANSI A208.1-1993 (NPA, 1993) and IS: 3087 -1985 (Anon, 1985) as well as British Standard BS: 5669 (Anon,1979) and German Standard DIN 64761 (Verkor and Leduge, 1975). But according to Australian and New Zealand standard (AS/NZA1859.1: 2001.int), the moisture content of standard particleboard is 5%-8% (The Laminex Group, 2003).

4.2.1.3 Water absorption

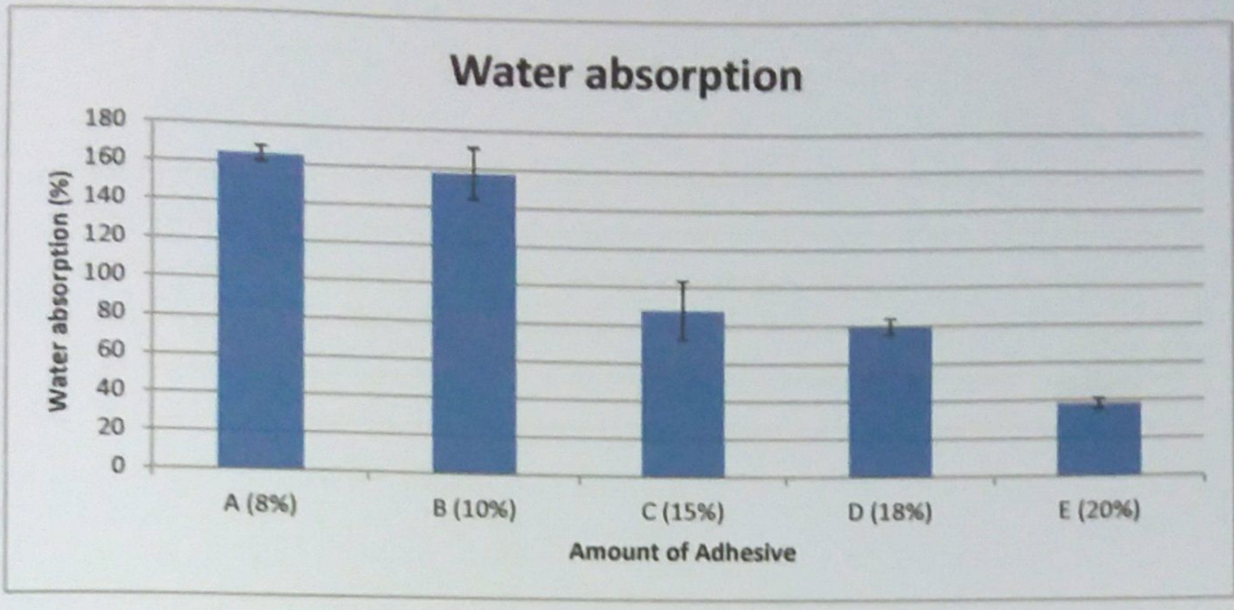

Figure 4.3: Water absorption (%) (after 24 hour) of particleboard with different ratio of adhesive.

I found that after 24 hour soaking the percentages of water absorption were 165%, 152.94%, 86.95%, 79.41% and 38.29% for particleboard of 8%, 10%, 15%, 18% and 20% respectively. According to IS specification 3087 (Anon, 2985) the absorption of water by standard particleboard is 50% after 24 hour soaking. The water absorption percentage by standard particleboard was not found per ANSI A208.1-1993 (NPA, 1993) as Australian and New Zealand Standard (AS/NZS 1859.1: 2001.int), (The Laminex group, 2003), British Standard BS: 5669 (Anon, 1979) and German Standard DIN 68 761 (Verkor and Leduge, 1975).

4.2.1.4 Thickness Swelling

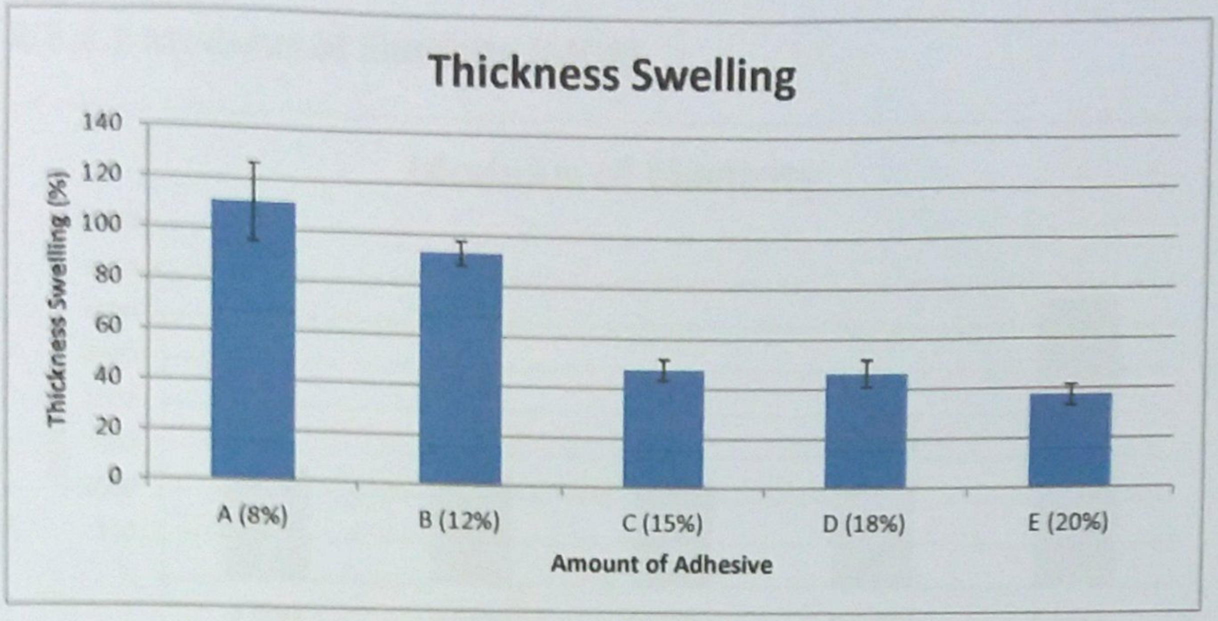

Figure 4.4: Thickness swelling (%) (after 24 hour) of particleboard with different ratio of adhesive.

I found that after 24 hour soaking the percentages of thickness swelling were 110.95%, 92.87%, 47.54%, 46.47%, and 37.41% for the particleboard made of 8%, 10%, 15%, 18% and 20% respectively.

The thickness swelling percentage after 24 soaking in water by standard particleboard was not found as per ANSI A208.1-1993 (NAP, 1993) and IS: 3087-1985 (Anon, 1985) as well as British Standard BS: 5669 (Anon, 1979) and German Standard DIN 68 761 (verkor and leduge, 1975). But Australian and New Zealand Standard (AS/NZS 1859.1: 2001.int), the thickness swelling of standard particleboard is 15% after 24 hours immersion in water for 18 mm thick board (The Laminex Group, 2013).

4.2.2 Mechanical properties

4.2.2.1 Modulus of Elasticity (MOE)

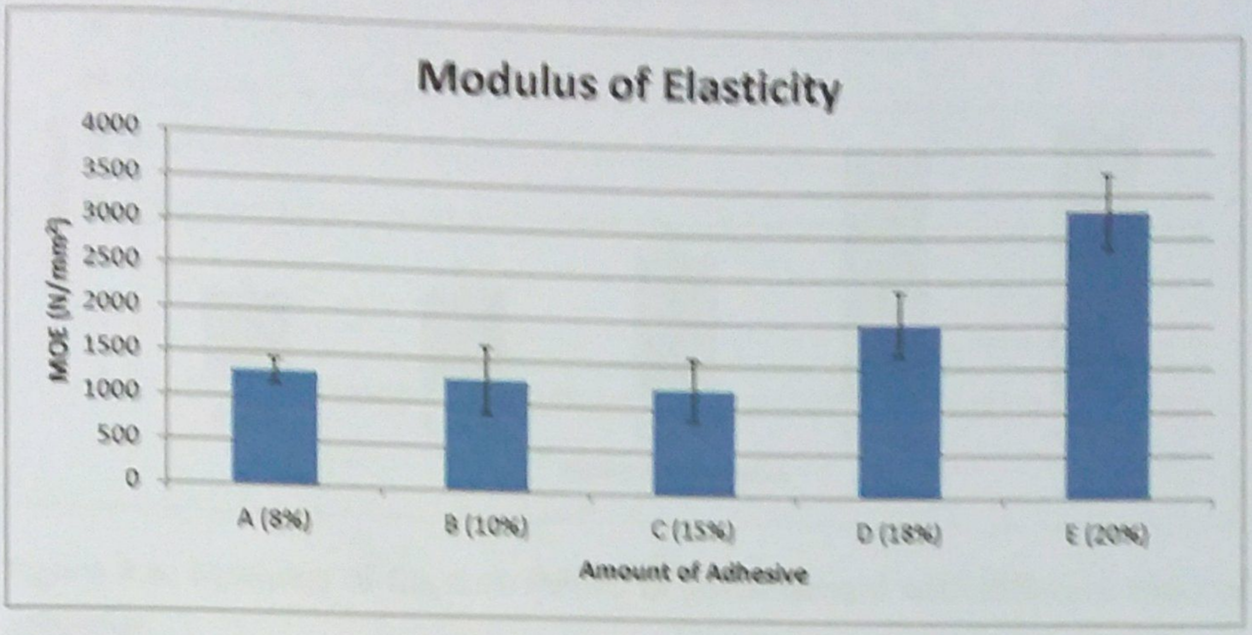

Figure 4.5: Modulus of Elasticity (MOE) of particleboard with different ratio of adhesive.

I found that the MOE of *Trema Orientalis* were 1292.77 N/mm^2, 1274.5 N/mm^2, 1211.95N/mm^2, 2010.54N/mm^2 and 3311.64 N/mm^{2}for particleboard made of 8%, 10%, 15%, 18% and 20% adhesive respectively.

According to ANSI A208.1-1993 (NAP, 1993), the MOE of standard particleboard is 2400-2750 N/mm^2 for high density grade, 1725-2750 N/mm^2 for medium density grade and 550-1025 N/mm^2 for low density grade. But according to Australian and New Zealand Standard (AS/NZS 1859.1: 2001.int), the MOE of Standard particleboard is 2500 N/mm^2 (for 18 mm thick board) (The Laminex Group, 2003).

4.2.2.2 Modulus of Rupture (MOR)

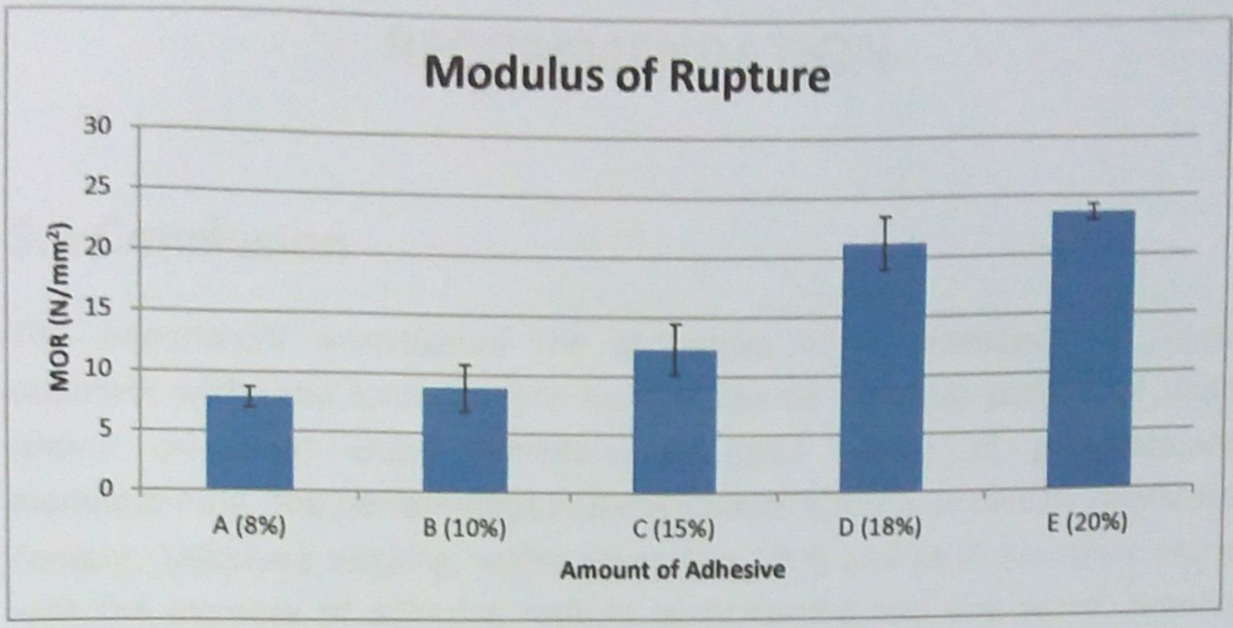

Figure 4.6: Modulus of Rupture (MOR) of particleboard with different ratio of adhesive.

I found that the MOR of *Trema Orientalis* were 7.84N/mm^2, 8.85N/mm^2, 12.30 N/mm^2, 21.22 N/mm^2 and 23.64N/mm^{2}for particleboard made of 8%, 10%, 15%, 18% and 20% adhesive respectively.

According to ANSI A208.1-1993 (NAP, 1993), the MOR of standard particleboard is16.5-23.5 N/mm^2 for high density grade, 11.0-16.5 N/mm^2 for medium density grade and 3.0-5.0 N/mm^2 for low density grade. According to IS: 3087-1985 (Anon, 1985), the MOR of standard particleboard is 10.98 N/mm^2. But according to Australian and New Zealand Standard (AS/NZS 1859.1: 2001.int), (The Laminex Group 2003), British Standard BS: 5669 (Anon, 1979) and German Standard DIN 68 761 (Verkor and Leduge, 1975), the MOR of standard particleboard is 16 N/mm^2(for 18 mm thick board), 13.80 N/mm^2 and 17.65 N/mm^2 respectively.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This experiment investigated the properties of particleboard of *trema orientalis* with urea formaldehyde resin. It can be said that particle of Jibon (*trema orientalis*) wood contribute as good source of particleboard manufacturing. The performance of particleboard if terms of density, moisture content, Thickness swelling, water absorption MOR and MOE increases along with the increase of adhesive ratio in particleboard and vice versa. Among those particleboard of 20% resin has satisfied most in case of physical and mechanical properties. If Jibon (*trema orientalis*) is used commercially for manufacturing particleboard, it will be a good source of raw material for particle board. As it is a fast growing species, widely used as fuel wood and charcoal production, government and industries owners may take initiatives for utilizing Jibon (*trema orientalis*) as a source of raw material for particleboard manufacturing.

5.2 Recommendation

In my study I investigate properties of particleboard of Jibon (*trema orientalis)* with different ratio of Urea formaldehyde (UF). But further can also be carries out with different adhesives like Phenol Formaldehyde (PF), Melamine Formaldehyde (MF), Poly Vinyl chloride (PVC), Poly Vinyl acetate (PVCA) or Citric acid etc. for manufacturing particleboard from Jibon (*trema orientalis*).

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APENDIX: ANALYSIS OF VARIANCE

Table A – 1: ANOVA for Moisture Content

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	173.2688	4	43.3172	1.4769	0.334896	5.192168
Within Groups	146.6491	5	29.32981			
Total	319.9179	9				

Table A – 2: ANOVA for Water Absorption

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28285.84	4	7071.459	20.37467	0.002696	5.192168
Within Groups	1735.356	5	347.0711			
Total	30021.19	9				

Table A – 3: ANOVA for Thickness Swelling

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8374.649	4	2093.662	20.37012	0.002697	5.192168
Within Groups	513.9051	5	102.781			
Total	8888.555	9				

Table A – 4: ANOVA for Modulus of Elasticity (MOE)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4522440	4	1130610	1.75881	0.273821	5.192168
Within Groups	3214133	5	642826.5			
Total	7736573	9				

Table A – 5: ANOVA for Modulus of Rupture (MOR)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	408.4037	4	102.1009	15.75439	0.004859	5.192168
Within Groups	32.40395	5	6.480791			
Total	440.8077	9				