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Programme: Bachelor of Science in Forestry

A STUDY ON

UTILIZATION OF BROWN MUSTARD (*Brassica juncea* (L.) Czern) PLANT RESIDUES AS A RAW MATERIAL FOR MANUFACTURING OF PARTICLE BOARD

MD TANBHEER RANA

Student ID : 100527

This thesis paper has been prepared for the partial fulfillment of the requirements of four (4) years professional B. Sc. (Hons.) degree in Forestry from Forestry and Wood Technology Discipline, Khulna University Khulna, Bangladesh.

FORESTRY AND WOOD TECHNOLOGY DISCIPLINE
KHULNA UNIVERSITY
KHULNA-9208
BANGLADESH

2010

بسم الله الرحمن الرحيم

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DECLARATION

I, **Md. Tanbheer Rana**, declare that this thesis is the result of my own works and it has not been submitted or accepted for a degree in any other university.

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Dedicated To My Beloved Parents and Little Sister

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Md. Tanbheer Rana

ABSTRACT

Particle board is mostly used alternative to wood at present age to reduce the pressure on solid wood. Different raw materials, mostly woody and non woody materials are used as raw material. In many cases, vegetable wastages are also utilized. A study was conducted to evaluate the feasibility of using Brown Mustard (*Brassica juncea* (L.) Czern) plant residues to manufacture particleboard. The physical and mechanical properties of brown mustard board was tested to access its quality. The particle board made from brown mustard waste presents good physical and mechanical properties. It was found that the density of brown mustard particleboard was 0.84 gm/cm^3, moisture content was 6.95%, water absorption was 41.86 %, thickness swelling was 18.75 %, linear expansion was 1.06%, Modulus of Rupture was 22.28 N/mm^2 that satisfied world standard value (21 N/mm^2) of ANSI (NPA, 1994), and Modulus of Elasticity of the particleboard was 2546.94 N/mm^2 that satisfied world standard value (2400 N/mm^2) of ANSI (NPA, 1994).The physical and the mechanical properties of some other particle boards made from other raw materials are also overviewed.

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ABBREVIATION

Anon	Anonymous
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
OD	Oven Dry Dimension
rpm	Rotor per minute
SD	Standard deviation
UF	Urea Formaldehyde
UTM	Universal Testing Machine
WP	Wood particle

1.1 Background and Justification of the Study:

The world as we know it, the forest around us is decreasing with the ever increasing pressure created to the forest products. Most commonly, timber is the focused target behind the use of entire forest products. Products demand is increasing, but a sustainable way of extracting products from forest can ensure to meet the demand without destroying the resources. Modern wood science has invented many alternatives ways to fulfill this target. Particle board is one of the major ways to reduce the pressure on solid wood. The use of wastage materials for manufacturing these substitutes of solid wood is also at reasonable price.

Wood is one of earth's most valuable and abundant renewable natural resources, which can be used for indefinite period of times (Lahiry, 2001). It is a gift of nature and is the only working material that is self generating (FAO, 1986). It is a material used by man for thousands of years without precise knowledge of its properties (Wangaard, 1981). Wood from times immemorial has been the most useful of all the readily available materials to mankind.

Particleboard is a panel product made by compressing small particles of wood composites while simultaneously bonding them with an adhesive. These composites are strong, stiff and resistant moisture, fire, fungi and insects. In panel form, they are being utilized for structural and non-structural application in both interior and exterior situations. Discovering new methods of manufacturing technologies to replace the conventional ones, and expanding its raw materials are some of the aspects that are increasing in momentum. The basic concept of incorporating plant fiber or particles, such as wood particles or agricultural residues, with inorganic matrices is very old. Worldwide economic growth and development have generated unprecedented needs for converted forest products such as pulp and paper, composite boards, plywood and lumber (Youngquist et al., 1993). This global demand started with the advent of the industrial revolution resulting in aggressive deforestation (Adger and Brown, 1994).

Various raw materials are being used to improve the quality of particleboard and to determine the study would be reliable or not with respect to the current situation. A wide variety of resources, i.e. jute, bagasse, wheat straw, rice husk, date palm stick, ground nut shell, and so on are being used in producing laboratory based particle board. In Bangladesh, most commonly used raw material for particle board preparation in large scale are Jute (*Corchorus olitorius)*, Mahogony (*Swietenia mahogany*), Kadam (*Anthocephalus chinensis*), Chatian (*Alstonia scholaris)*, Akashmoni (*Acacia auriculiformis*), etc. Due to massive extraction of these raw materials of particleboard preparation, these species now in short supply. So, possible alternative source of raw materials are encouraged to reduce extensive pressure on similar kind of species. Brown mustard plant residues are the left portion of the plant after extracting the mustard seeds. The residues of this plant are usually left in the field for deterioration and in some cases; these residues are used as fuel. This plant produces cheap, abundant, easily available residues that can be suitable of particle board preparation because of its lingo-cellulosic materials. Almost any agricultural residue after suitable treatment can be used as raw material for particle board preparation (Salehuddin, 1992). In addition to that, there is no evidence of using this brown mustard residue as raw material for particle board preparation. That is why; this study have been attempted to find out the possible outcome of using brown mustard residues as raw material for preparing particle board.

1.2 Objectives of the study:

The objective of this study is to evaluate the physical and mechanical properties of Brown Mustard made particle board. In order to figure out the quality of the particle board, different laboratory tests has been conducted and reasonable parameters has been measured. The study consisted of the following specific objectives.

- To evaluate the feasibility of brown mustard plant residues for production of particle board.

2. General Information about Particleboard

2.1. Definition of Particleboard

Particleboard is a substitute of natural wood. Due to deforestation, natural wood is becoming scarce. For this now a days, particle board are being made from agricultural residues, saw dust, non commercial waste wood chips etc. Particleboard is defined as a panel material manufactured from lingo-cellulosic fibre material, usually wood, primarily in the form of discrete pieces of particles as distinguished from fibres. The particles are combined with synthetic resin or other suitable binders and bonded together under heat and pressure in a hot press by a process in which the entire particle bond is created by the added binder. Other materials may be added during manufacture to improve certain properties. (Anon, 1967; Tsoumis, 1991).

The production of particleboard is the efficient utilization of wood. The production of yield is higher (75-90% or more) in comparison to lumber and plywood (about 50%) (Tsoumis, 1991). Growth of particleboard industries in many countries occurred due to the possibility of utilizing small dimension wood including residues from other wood industries, availability of synthetic resins that facilitate mass production by fast curing, suitability of the product for a variety of uses (furniture, building construction etc.) and the possibility of producing boards with large dimensions and to customers specifications (Moslemi, 1985).

2.2. History and Development of particle Board

In 1902, Earnst Hubbard published a paper, "The Utilization of Wood-Waste". This was the first publication about making the particleboard (Eastman, 1997). The particleboard panels were made by hot pressing a mixture of sawdust and blood albumen. In 1905, Watson, an American inventor, invented a modern flake board by using wood particles. In 1914, Cari G. Muench produced particleboard panel using a technology similar to papermaking. In 1940, Humble found a way to utilize large volume of sawdust and planer shavings in Germany. In 1941, during the World War II, one of the factories in Bremen, Germany started using spruce chips and phenolic adhesives for manufacturing particleboard panels. Farley and Loetscher Mfg Co., an American manufacturer, also started to produce the particleboard in the US during the same period of time. At that time, the particleboard market grew rapidly in Europe and US. First unsuccessful efforts were made in the early 1920's for manufacturing as for the lack of suitable adhesives. New techniques introduced in the 1930's in resin applications paved the way for the industrial production of particleboard in the early 1940's (Moslemi, 1985).

2.3. Raw materials for particleboard manufacturing

2.3.1.1 Woody materials

Planer savings, Sawmill residues, such as slabs, edging, trimmings, Saw dusts, Logging residues, such as short logs, broken logs, crooked logs, small tree tops and branches, forest thinning , etc, and Bark (Salehuddin, 1992)

2.3.1.2 Non-woody materials

Jute sticks, Bagasse, Bamboo, Flax shaves, Cotton stalks, Cereal straw, Almost any agricultural residue after suitable treatment (Salehuddin, 1992).

2.3.2 Chemicals

2.3.2.1 Binder or Adhesive

Adhesives are substances capable of holding materials together in a useful manner by surface attachment. The principle attribute of adhesives is their ability to form strong bonds with surfaces of a wide range of materials and to retain bond strength under expected use conditions (Lehman, 2004).

2.3.2.1.1. Types of adhesive/ binder

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

- **Synthetic adhesive or synthetic resin adhesive**

Adhesives of synthetic origin are called synthetic adhesives. These are man-made polymers which resemble natural resins in physical characteristics but which can be tailored to meet specific wood working requirements. Synthetic adhesives can be categorized into two groups, namely 1) Thermosetting adhesives and
2) Thermoplastic adhesives.

- ✓ **Thermosetting adhesives**

Thermosetting adhesives undergo a chemical change during application and curing. The bonds formed by thermosetting adhesives are generally moisture resistant and support loads under normal use. During the polymerization, thermoset polymers form links, between adjacent chains. The level of cross linking can be varied. Materials with high cross – linking densities are hard, rigid and somewhat brittle substances. Thermosets with low cross – linking densities can be softened by heating to high temperatures, but they do not melt and their original shape is retained (Gilleo et. al., 2005).

Some characteristics and uses of some thermosetting adhesives are–

i. **Phenol formaldehyde:**

Is the oldest class of synthetic polymers, having been developed at the beginning of the 20th century (Detelefsen, 2002). These resins are widely used in both laminations and composites because of their outstanding durability.

ii. **Urea-formaldehyde (UF)**

Resins are typically used in manufacturing of products where dimensional uniformity, surface smoothness are of primary concern, for example particleboard and MDF. Products manufactured with resins are designed for interior applications. The inherent light color of the UF resins make them suitable for the manufacture of decorative products (Youngquist, 1999).

iii. **Melamine-formaldehyde (MF)**

Resin is typical of those used in the particleboard and MDF (medium density fiber board) industry. The moisture resistance of UF can be improved by adding MF (APA, 2005 and Youngquist, 1999).

✓ **Thermoplastic adhesives**

Thermoplastic adhesives are especially useful because they can be used in a dry form and are already fully polymerized as received. The bonding process basically involves softening the polymer while in contact with their adherents, and allowing the joint structure to cool. Common wood adhesives that are based on thermoplastic polymers include polyvinyl acetate emulsions, contacts, hot-melts etc. (Vick, 1999).

2.4. Types of particleboard

2.4.1 Types of particle used

a) **Flake board:** particleboard in which the wood is largely in the form of flakes, giving the surface a characteristic appearance, b) **Chip board:** A particleboard made from chips. c) **Shaving board:** A particleboard in which wood shavings are the chief constituents.

2.4.2 Pressing method used

a) ***Flat press process***, where pressure is applied perpendicular to board surface, particles generally falling flat along the plane of the board surface, b) ***Extrusion process***, where resin-bonded particles are forced between parallel hot plates or dies for consolidation and cure, particles lying largely at right angles to the board surface, and c) ***Molding process***, where products are molded in to the desired shape with heat and pressure by using specially constructed mould or dies.

2.4.3 Particle size distribution in the thickness of board

a) **Single layer** or homogeneous board, b) **Three layer board**, where course particles in the core layer are sandwiched between fine particles in the face layers, and c) **Multi-layer** or graduated board, with a graduation of particle ranging from the finest in the face layer to the coarsest in the core.

2.4.4 Density of the particleboard

a) **Low density** particleboard (below 590 kg/m^3), b) **Medium density** particleboard (590 – 800 kg/m^3), and c) **High density** particleboard (above 800 kg/m^3)

2.4.5 Types according to Australian standards

a) **Standard particleboard:** Particleboard suitable for general purpose and dry interior use. It is not suitable for exterior use or interior areas where wetting or prolonged high humidity conditions are likely. b) **Moisture resistant (MR) particleboard:** Particleboard suitable for areas of occasional wetting and high humidity. Not suitable where submerging, hosing or continual wetting is likely to occur. c) **High performance (HP) particleboard:** Particleboard suitable for use in certain structural applications. d) **Particleboard for flooring:** Particleboard manufactured specifically for use as domestic or industrial flooring (AWPA, 2008).

2.5 Uses of particleboard

Particleboards are used as flush-door cores and sliding doors, domestic, institutional and office furniture, cabinets and displays, kitchen and stereo/ TV cabinets (Haygreen et al., 1996), book cases and shelves, table and counter tops, table tennis table and tool table, electronic game consoles (Nemli et al., 2005), floor underlayment etc.

2.6. Advantages of particleboard

- Particleboards ensure complete utilization of raw materials.
- The characteristic defects of wood such as knots, spiral grain, etc., may either be eliminated throughout the particleboard manufacturing.
- Particleboard may be manufactured suitable for exposure to weather, for interior use, for interior paneling, for exterior sideboards, for load bearing flooring purposes and so on.
- Perhaps the most important advantage of particleboard is that it can be made in large dimensions (Salehuddin, 1992).

2.7. Considerations for the quality of particleboard

- **Particle geometry and slenderness ratio (s).**

Particle geometry plays an important role in the board properties. The main aspect of particle geometry is the slenderness ratio (s), i.e., the ratio of length (l) over thickness (t) of particles with square or rectangular cross-section, $s = l/t$, or the ratio of length over diameter (d) for round particles, $s = l/d$ (Arabi et al., 2011).

- **Raw materials and compression ratio.**

Practically all the physical and mechanical properties of particleboard depend on the board density as well as raw materials density. Particleboard must be compressed during hot pressing from 5 percent to 50 percent. Lower-density raw materials have greater compression ratio (Marian, 1983).

- **Glue mixing proportion and blending.**

Glue mixing proportion is an important factor that affects the properties of particleboard. If glue has the higher water content then it affects adversely the board properties, creates blisters on the surface during pressing and increases the final moisture content of the board (Edler, 1979).

2.8 Manufacturing procedure of particleboard

2.8.1 Particle reduction from raw materials

- Crosscutting, Splitting
- Primary reduction, Knife Hogs.
- Secondary reduction, Hammer-Mill Hogs, Toothed Disc-Mills, Impart Disc-Mills.
- Sharing or Flake Production, Disc Type Chippers, Cutter Spindle and Cutter Cylinder chippers (USEPA,2015).

2.8.2 Particle drying and screening

The greater part of the furnish delivered to the mill needs to be dried so that the overall moisture level of the particles is in the order of three to eight percent for the purpose of bonding with liquid resins (Papadapolous, 2006). Directly after drying, the particles are screened for size in vibrating screen. It is essential that the oversized particles be recycled for further reduction and that the fines are screened out, so as to avoid consuming a disproportionate amount of resin binder, and to provide a valued source of fuel (FAO, 2015).

2.8.3 Blending and mat forming

Adhesives in the form of urea, phenol and melamine formaldehyde are generally used to bind together the particle mix, with the former being the most favored resin in use. Between three and ten percent by weight of resin, together with other additives are used.

2.8.4 Pressing

Pre-pressing of the mats prior to the introduction in the multi-platen hot presses, is now becoming a common feature in the pressing operation, due to the consolidation and reduction in mat width. This allows for ease of handling and the use of narrower openings in the hot-press, thereby considerably reducing pressing time.

2.8.5 Board finishing

On leaving the hot press the boards are either separated from the cauls by hand, or mechanically by means of chains or turning devices. The boards in turn, are cooled and conditioned so as to avoid degradation of the urea resins. Trimming saws are used to cut the boards to size, with the edge trimmings being either recycled or used for fuel (FAO, 2015).

*2.9 General information about Brown Mustard (***Brassica juncea** ***(L.) Czern).***

2.9.1 Classification of Brown Mustard:

Kingdom Plantae – Plants

Subkingdom Tracheobionta – Vascular plants

Superdivision Spermatophyta – Seed plants

Division Magnoliophyta – Flowering plants

Class Magnoliopsida – Dicotyledons

Subclass Dilleniidae

Order Capparales

Family Brassicaceae/Cruciferae – Mustard family

Genus *Brassica* L. – mustard

Species *Brassica juncea* (L.) Czern. – brown mustard

(USDA Plant Database, 2015)

2.9.2 Subordinate Taxa

2.9.2.1 Non-preferred Subordinate Taxa

- ***Brassica juncea*** **subsp.** ***integrifolia***
- ***Brassica juncea*** **subsp.** ***integrifolia*** **var.** ***crispifolia***
- ***Brassica juncea*** **subsp.** ***integrifolia*** **var.** ***integrifolia***
- ***Brassica juncea*** **subsp.** ***integrifolia*** **var.** ***japonica***
- ***Brassica juncea*** **subsp.** ***integrifolia*** **var.** ***longidens***

2.9.2.2 Common names

Brown Mustard (*Brassica juncea* (L.) Czem) is a well known annual crop.

English- Mustard Greens, chicken mustard, Indian mustard. Leaf mustard

Chinese- Jie cai, shui cai

French-Moutarde de chine, moutarde brune, moutarde frisee

German- Ruten-Kohl, brauner senf, sarepa-senf

Hindi-Raya, rai

Bengali- Sorisha

(U.S. National Plant Germplasm System, 2015)

2.9.3 Distribution

Primary center of Brown Mustard (*Brassica juncea* (L.) Czern) of the origin thought to be central Asia (northwest India), with secondary centers in central and western China, eastern India, Burma, and through Iran to Near East. Has been cultivated for centuries in many parts of Eurasia. The principle growing countries are Bangladesh, Central Africa, China, India, Japan, Nepal, and Pakistan, as well as southern Russia north of the Caspian Sea (Duke, 1983).

2.9.4 Plant Morphology

Perennial herb, usually grown as an annual or biennial, up to 1 m or more tall; branches long, erect or patent; lower leaves petioled, green, sometimes with a whitish bloom, ovate to obovate, variously lobed with toothed, scalloped or frilled edges, lyrate-pinnatisect, with 1–2 lobes or leaflets on each side and a larger sparsely setose, terminal lobe; upper leaves sub entire, short petioled, 30–60 mm long, 2–3.5 mm wide, constricted at intervals, sessile, attenuate into a tapering, seedless, short beak 5–10 mm long. Rooting depth 90–120 cm. Seeds about 5,660–6,000per 0.01kg(1/3oz) (Duke,1983).

Fig 2.1: Morphology of plant

(a) Flower **(b) Fruit** **(c)Leaf**

2.9.5 Propagation and management

Ranging from Boreal Wet to Tropical Thorn through Tropical Wet Forest Life Zones, Indian Mustard is reported to tolerate annual precipitation of 500 to 4,200 mm, annual temperature of 6 to 27°C, and pH of 4.3 to 8.3. Rai is grown mostly as a rain fed crop but grows well in some dry parts of northern and central Africa, northern India, and the interior of China. It is moderately tolerant of soil acidity, preferring a pH from 5.5 to 6.8. Thrives in areas with hot days and cool nights and is fairly drought resistant. Seeds sown in very early spring for spring use and in the fall for winter use. Successive plantings 10–14 days apart insure an all season crop. Sown in drills 30–45 cm apart; plants thinned to about 15 cm as they become crowded in the row. Control of weeds is essential, and 1 to 3 inter cultivations may be necessary. Manure or soil improving crops may also be used. Nitrogen increases seed yield. This crop should not follow other Brassica crops in rotation. For disease control, it is best grown once every 3–4 years (Duke, 1983)

2.9.6 Pests and Diseases

Fungi known to attack rai or brown mustard are: *Albugo candida, Albugo macrospora, Alternaria brassicae, Alternaria saccardoi, Ascochyta brassicae-junceae, Cercospora brassicicola, Cercosporella albomaculans, Cercosporella brassicae, Cladosporium brassicicola, Collectotrichum higginsianum, Cystopus candidus, Erysiphe polygoni, Ischnochaeta polygoni.* Bacteria include: *Erwinia carotovora* and *Xanthomonas campestris* (Duke, 1983).

2.9.7 Traditional Uses of Investigated Species:

The plant appears in some form in African, Bangladeshi, Italian, Indian, Chinese, Japanese, Korean, and African-American (soul food) cuisine. Cultivars of *B. juncea* are grown as greens, and for the production of oilseed. B. juncea can hyper accumulate cadmium and many other soil trace elements. Especially cultured, it can be used as selenium, chromium, iron and zinc food supplement. This plant is used in phyto-remediation to remove heavy metals, such as lead, from the soil in hazardous waste sites because it has a higher tolerance for these substances and stores the heavy metals in its cells.

3.1 Materials and Methods

3.1.1 Chipper

A locally made small lab scale chipper was used to chip the raw materials. The rpm of the chippers' motor was 1420.

3.1.2 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 particleboards.

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 particleboards.

3.1.4 Hot press

A digital hydraulic hot press was used to press the mat into particleboard. Maximum temperature range within 400°C and pressure up to 5MPa commonly occur.

3.1.5 Universal Testing Machine (UTM)

An analogue Universal Testing Machine (UTM), model: WE-100, made by Time group Inc. was used to determine the mechanical properties of the particleboards.

3.2 Manufacturing of Particle Boards

3.2.1 Collection of Raw Materials

Brassica juncea (L.) Czern plant residues were obtained locally. The dried plant after extraction of mustard seed is considered as the residues that is mostly used as fuel wood in village households. As an anuual crop, the plants were of one year of age and having a height of approximately half to one meter. The entire plant excluding the seeds, leaves and roots were considered as the raw matrial for this study, i. e. branches and stems. The raw materials for particleboard manufacturing were collected from Satkhira, Bangladesh.

3.2.2 Processing of Raw Materials

The dried plant of brown mustard was collected and stored. The leaves and roots were removed after drying the plant. In order to make the raw material more brittle, it was then dried under sunlight for few days. This dried raw material was manually chipped by the use of a sharp chopper to reduce the size to a usable limit. The chips were then fed into laboratory grinder to produce desired particle. The size was controlled by the use of a mesh opening at 2 mm. The grinded particles were then mixed uniformly in order to ensure better performance.

3.2.3 Drying of Raw Materials

After that, the raw materials were dried in an electrically heated lab scale oven at 83±3°C for 4 hours. For use with binder, the particles must be dried and moisture content reduced to about 2% to 7% moisture content.

3.2.4 Mat Formation

Raw materials were blended manually with Urea Formaldehyde (UF) resin. The type and amount of resin used for particleboard depend on the type of product desired. Based on the weight of dry resin solids and ovendry weight of the particles, the resin content can range between 4% and 10%, but usually ranges between 6% and 9% for UF resins. (Youngquist, 1999). Here, 9% Urea Formaldehyde is mixed with raw materials.

Fig 3.1: Mat Formation

Mat had the dimension of 200 mm × 150 mm. Initial mat thickness was about 7 times higher than the targeted board.

3.2.5 Hot Pressing

A steel sheet was placed on the mat after finishing mat formation. Then, mats were pressed on a computer controlled hot press under temperature at 150 ° C and 5MPa pressure for 10 minutes. The temperature switch was switched off after

10 minutes. Hot-press temperatures for thermosetting materials (e.g. UF, RF, PF) usually range from 140°C to 165°C (284°F to 325°F). (Youngquist, 1999)

Fig 3.2: Particle Board of Brown Mustard Plant residue

3.2.6 Conditioning

After stopping temperature the board was remained fixed for conditioning. The hot boards are removed from the press and further conditioned to equilibrate board moisture content and to stabilize and fully cure the adhesives (AWPA, 2001).

3.2.7 Trimming

Boards were trimmed at edges with the fixed type circular saw. The boards were 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).

3.2.8 Sanding

Sanding Operation is performed to reduce thickness variation and improve surface paintability. So, the trimmed boards were sanded with 80 grade sand paper with a rough sanding surface.

3.3 Manufacturing Place

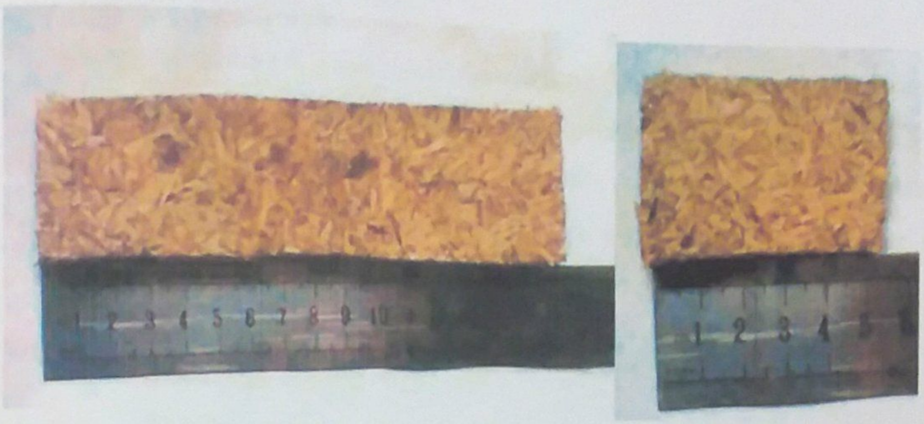
The particle board was manufactured at Laboratory of Pulp and Paper Technology and Wood Composite and Wood Laboratory of Forestry and Wood Technology Discipline, Khulna University.

3.4 Laboratory Test

The laboratory tests were carried out 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.

The dimension of samples for testing the physical and mechanical properties were approximately (50 mm × 35 mm × 6 mm) and (160 mm × 35 mm × 6 mm) respectively.



(a) (b)

Fig 3.3: Samples for Mechanical and Physical Tests Resepctively

3.4.1 Physical Properties

<u>3.4.1.1 Density and Density Distribution</u>

The density and moisture content of each board were calculated through measuring initial weight and oven-dry weight where oven-dry weight were obtained by drying the samples at 83±2°C until reaching a constant weight. The samples weight and dimensions of every board were measured respectively by an electric balance and a digital slide caliper. The volume of each sample was calculated as a result of multiplying the length, width and thickness.

Density (D) of each board was calculated after measuring weight and volume using the following equation-

$D = \frac{m}{v}$; Where m is the mass and v is the volume of each sample (Desch and Dinwoodie, 1996).

3.4.1.2 Moisture content

After measuring the initial mass and oven-dry mass moisture content (MC) was determined by following equation.

$mc\ (\%) = \frac{m_{int} - m_{od}}{m_{od}} \times 100$; Where m_{int} is the initial mass and m_{od} is oven-dry mass of the sample (Desch and Dinwoodie, 1996).

3.4.1.3 Water Absorption

The water absorption (A_w) and thickness swelling (G_t) were determined by soaked in water for 24 hours. The water absorption and thickness swelling rate were increased with the time passed. After 24 hours the water absorption and thickness swelling were calculated by an electric balance and a digital slide caliper as a percentage.

Water absorption was calculated by the following formula-

$A_w(\%) = \frac{m_2 - m_1}{m_1} \times 100$ (ASTM, 1997) ; Where m_1 is the weight of the sample before immersion and m_2 is the weight of the sample after immersion in water.

3.4.1.4 Thickness Swelling

Thickness Swelling was determined by using the following equation-

$G_t = \frac{t_2 - t_1}{t_1} \times 100$(ASTM, 1997) ; Where t_1 is the sample thickness before immersion and t_2 is the sample thickness after immersion into water. (Desch and Dinwoodie, 1996)

3.4.1.5 Linear expansoin

The Linear Expansion was calculated by the following formula-

$LX(\%) = \frac{L_A - L_B}{L_B} \times 100$(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).

3.4.2 Mechanical Properties

By using Universal Testing Machine followed by three point bending test modulus of elasticity (MOE) and modulus of rupture (MOR) were determined for each board. MOR and MOE were calculated by following formulas-

$MOE = \frac{P / L^3}{4\Delta / bd^3}$; $MOR = \frac{3PL}{2bd^2}$ (Desch and Dinwoodie, 1996)

In both equations, MOE and MOR is the modulus of elasticity (N/mm^2) and modulus of rupture (N/mm^2); P represents load in the limit of proportionality (N); L is the length of the span (mm); b is the width (mm); d is the thickness (mm) and Δ represents the deflection at the limit of proportionality (mm).

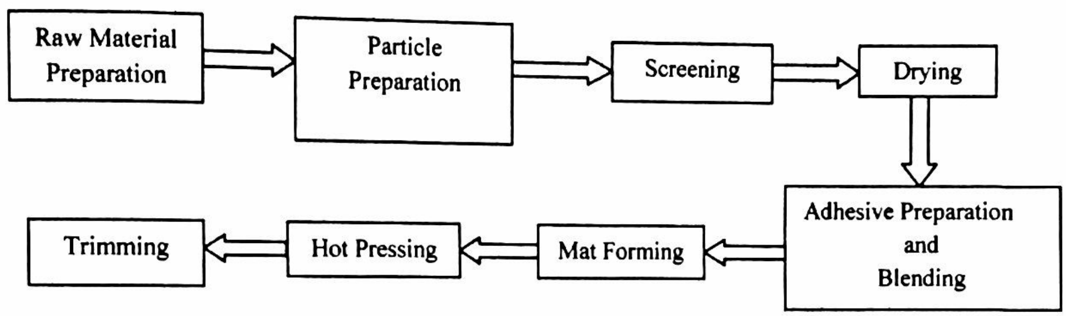


Fig 3.4: Flowchart of particle board preparation

3.5 Statistical Analysis

The data of the physical and mechanical properties of brown mustard board were collected. Similar results of some other particle boards having different raw materials were shown to have an idea of utilizing brown mustard plant residues as a raw material. Nine boards were prepared for testing the properties with three replications. The best result of the prepared board is presented.

All the data, produced during the laboratory tests for characterization of physical and mechanical properties of each type of particleboards, were analyzed by SPSS 16.0 (Statistical Package of Social Survey) software.

4.1 Results and Discussions

4.1.1 Physical properties

Properties	Brown Mustard Board	Upper	Lower
Density (kg/m³)	836.03±17.79	836.03	789.51
Moisture Content (%)	6.95±0.32	6.98	6.25
Water Absorption (%)	41.86±2.60	48.69	41.86
Thickness Swelling (%)	18.75±0.69	20.61	18.75
Linear Expansion (%)	1.06±0.07	1.24	1.06

The density of brown mustard board was 836.03 kg/m³, moisture content after curing was 6.95 %, water absorption after 24 hours was 41.86 %, thickness swelling was 18.75 %, and linear expansion was 1.06 %. The samples used for determining the physical properties were approximately of (50 mm × 35 mm × 6 mm) dimension, and went under 5 Mpa pressure, 150°C temperature, 10% UF resin content.

4.1.2 Mechanical properties

Properties	Brown Mustard Board	Upper	Lower
Modulus of Elasticity (N/mm²)	2546.94±204.87	2546.94	2013.89
Modulus of Rupture (N/mm²)	22.28±3.07	22.28	14.87

The MOR and MOE of brown mustard board were 22.28 N/mm² and 2546.94 N/mm² respectively. The dimension for determining the mechanical properties were (160 mm × 35 mm × 6 mm), and went under 5 Mpa pressure, 150°C temperature, 10% UF resin content.

4.1.3 Physical and Mechanical properties of some other boards

Properties	Brown Mustard Board	Dhaincha Board	Groundnut Shell Board	Dhol Kolmi Board	Wood Chips Board
Density(kg/m^3)	836.03	602.00	706.65	715	700.55
Moisture Content (%)	6.95	6.5	6.95	13.03	7.09
Water Absorption (%)	41.86	69.49	49.08	47.42	62.25
Thickness Swelling (%)	18.75	9.5	17.60	15.61	21.04
Linear Expansion (%)	1.06	0.67	1.11	0.73	1.28
Modulus of Elasticity(N/mm^2)	2546.94	2123.04	828.31	3868.9	2181.04
Modulus of Rupture(N/mm^2)	22.28	15.10	9.22	33.31	14.88

The physical and mechanical properties of the Dhaincha board (Islam et al., 2006), Groundnut shell board (Sarkar, 2012), Dhol kolmi board (Reja, 2015), and Wood chips board made from mixture of dhaincha and jute stalk (Sarker, 2012) are shown in the table. The specifications for the boards are noted below:

Name	Temperature	Pressure	Resin	Resin Percent
Dhaincha board	165	20	UF	15
Groundnut shell board	150	5	UF	20
Dhol kolmi board	140	3	UF	15
Wood chips board	160	17	UF	15

4.1.4 International Standards of Particle board

Properties	Brown Mustard Board	IS Specification 3087	German Standard DIN 68761	Australian and New Zealand Standard (AS/NZS 1859.1:2001.Int)	ANSI A208. 1-1993
Density(kg/m³)	836.03	500-900	590-750	-	-
Moisture Content (%)	6.95	-	-	5-8	-
Water Absorption (%)	41.86	50	-	-	-
Thickness Swelling (%)	18.75	-	-	15	-
Linear Expansion (%)	1.06	-	-	-	0.35
Modulus of Elasticity(N/mm²)	2546.94	-	-	2500	2400-2750 (High) 1725-2750 (Medium) 550-1025 (Low)
Modulus of Rupture(N/mm²)	22.28	10.98	17.65	16	16.5-23.5 (High) 11.0-16.5 (Medium) 3.0-5.0 (Low)

International standard values for physical and mechanical properties of the particle board are listed in above table. In some cases, the results of the standard for particular parameter were not found.

5.1 Conclusion

The density of Brown Mustard particleboard was 0.84 gm/cm^3, moisture content was 6.95%, water absorption was 41.86 %, thickness swelling was 18.75 % and linear expansion was 1.06%.

The MOR of the particleboard was 22.28 N/mm^2 that satisfied world standard value (21 N/mm^2) of ANSI (NPA, 1993). The MOE of the particleboard was 2546.94 N/mm^2 that satisfied world standard value (2400 N/mm^2) of ANSI (NPA, 1993).

The physical and mechanical properties of some particle boards made from other raw materials considering the parameter, and international standards are listed in tables to have an idea about the recent findings.

Considering the properties of particle board made from Brown mustard (*Brassica juncea* (L.) Czern.) plant residues, it can be said that, brown mustard plant residues could be a potential source of alternative raw material of manufacturing particle board.

5.2 Recommendations

Particle board preparation from brown mustard plant residues was conducted in laboratory. Even, it satisfied some international standards for mechanical and physical properties. Further studies on particle board preparation from brown mustard plant residues can be carried out, in order to improve the properties of the board, and it is highly encouraged.

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