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Comparative Study of the Mechanical and Physical Properties of Composite Board Manufactured from Til (*Sesamum indicum*) and Wheat Straw (*Triticium aestivum*)

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Comparative study of the mechanical and Physical properties of composite board manufactured from Til (*Sesamum indicum*) and Wheat straw (*Tritcium aestivum*).

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Dedicated To

My Parents and

Brothers

Declaration

This is SK. Mahabub Hasan, declaring that this thesis is the result of my own work and this work has not been accepted for any other degree in any other university.

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

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Certification

This is to certify that **SK. Mahabub Hasan**, Student ID: MS-120515, has prepared this thesis paper entitled "Comparative study of the mechanical and Physical properties of composite board manufacturing from Til (*sesamum indicum*) and Wheat straw (*Tritcium aestivum*), under my supervision and submitted to the Forestry and wood Technology Discipline, Khulna university, Khulna for partial fulfilment of the requirements for the Master's of Science (MS) Degree in Forestry under Forestry and wood Technology Discipline, Khulna University, Khulna. I do hereby approve the style and content of this paper.

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ABSTRACT

Til (*sesamum indicum*) and Wheat straw (*Tritcium aestivum*) are agricultural residues, cheap source for composite board manufacturing. In this study an attempt is made to understand the mechanical and physical properties of board made from Til (*sesamum indicum*) and Wheat straw (*Tritcium aestivum*) and also to understand the differences in these strength properties of Til board and Til, wheat straw combined board. The evaluated composite board properties were Density, Moisture Content (MC), Water absorption, Linear Expansion Thickness swelling, Modulus of Elasticity (MOE) and Modulus of Rupture (MOR). The density of Til board and Til, wheat straw combined boards are 713.33 Kg/m^3 and 626.34 Kg/m^3.The Moisture Content (MC) of these boards are 7.17 % and 6.92 % respectively. The Water absorption of Til board and Til, wheat straw combined board are 89.07 % and 94.00 % respectively.The Linear Expansion are 1.15% and 1.36 % .For Til board and Til, wheat straw combined board Thickness swelling are 47.25% and 55.13% . For Til board the MOE is 3792.9 N/mm^2 and MOR is 36.71 N/mm^2 .The MOE and MOR of Til, wheat straw combined board was 2827.1 N/mm^2 and 28.29 N/mm^2 respectively. Further study of Til (*sesamum indicum*) and Wheat straw (*Tritcium aestivum*) may increase the potential use as alternative sources of raw materials for composite board manufacturing based on its mechanical and physical properties.

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Chapter One: Introduction

1.1 Background and Justification

Composite board is a wood-based product manufactured under pressure and temperature using wood particles or other ligno-cellulosic materials can be attributed to the economic advantage of low-cost wood, other lingo-cellulosic fibrous materials and inexpensive processing with various types of binders (Anon, 2003). The demand for composite wood products, such as ply-wood, oriented strand board (OSB), hardboard, composite board, medium-density fiber board and veneer board products has recently increased substantially throughout the world (Sellers, 2000). Composite board is 57% of total consumption of wood-based panels consumed and it is continuously growing at 2–5% annually (Drake, 1997).composite is widely used in the manufacture of furniture, cabinets, stair treads, home constructions, tabletops, vanities, speakers, sliding doors, lock blocks, interior signs, displays, table tennis, pool tables, electronic game consoles, kitchen worktops, and work surfaces in offices, educational establishments, laboratories and other industrial products (Nemli et al. 2007) The past 50 years have seen the successful developments within the composite board industry. Much of this success can be attributed to the decided economic advantage of low cost wood raw material and inexpensive with binders (Hofstrand et al. 1984).

Accelerated deforestation and forest degradation, in addition to a growing demand for wood-based boards, have raised an important issue regarding the sustained supply of raw material to the above sectors for a long time (Colak et al. 2007). Consequently, there is a need for alternative resources to substitute wood raw material.

Therefore, researchers, both in industry and academia, are looking for new sources of lingo-cellulosic materials.Alternative fibers such as Agricultural residues are an excellent alternative to using virgin wood fiber for their abundance and renewability, using agricultural residues will benefit farmers, industry and human health and the environment. (Al Wong, 1997) agricultural residues and non-wood plant fibers could play a major role in providing the balance between supply and demand for the manufacturing of composite panels such as composite board. Research has been carried out on a wide variety of those mate-satisfying the standards of furniture industry have also been described. According to these studies, the use of straw fibers allows the production of panels over a larger range of densities, from0.2 to 0.8

g/cm3, in comparison with the wood panels, in which the production of panels with densities below 0.4 g/cm3 is impossible. Composite board performance is mainly related to the properties of adhesive used and its compatibility with wood. Several types of resins have been used to produce wood-based composite board. The most widely used resins are urea–formaldehyde (UF) and phenol–formaldehyde (PF) resins. However, in addition to the possible environmental problem resulting from the toxic formaldehyde emissions of UF and PF bonded composite board; Advantages of UF resins include lower curing temperatures than PF resins and ease of use under a variety of curing conditions. UF resins are the lowest cost thermosetting adhesive resins. They offer light colour, which often is a requirement in the manufacture of decorative products. However, the release of formaldehyde from products bonded with UF is a growing health concern. (Hervillard T, Cao Q, 2007).

The increased demands for raw materials in wood composite industries have led researchers to investigate non-wood ligno-cellulosic biomass utilization in composite manufacturing including composite board. Agricultural waste materials and annual plant fiber have become alternative raw materials for the production of particle or fiber composite materials. The most frequently referred alternative non-wood materials are flax, bagasse, hemp, reed, and cereal straws such as rice and wheat straw (Younquist et al. 1994). Today chemical pulp and panel products using wheat straw and other crop residues such as Til are being commercially manufactured in a number of countries (Copur et al. 2007).

Since the early 1981s, wood-based particle board is produced in Bangladesh. Recently the demand of composite boards increased all over the world for house construction, furniture manufacturing and interior decoration (wall and ceiling paneling) etc. due to its strength and workability. Therefore, it is manufactured in great quantities which results in large quantities of lignocellulosic raw materials consumption by the processing industries causing a threat to the natural forest as well as to the environmental Sustainability.

There is a perceived shortage of wood fibre for composite products due to competition for fibre by pulp mills, reduced harvesting and manufacturing and diminished log quality. Also, there is pressure from environmentalists to reduce forest use and regulatory legislation pending on disposal of agro fibres (Pande, 1998).

Most of the developing countries are very rich in agricultural and natural fibre. Except a few exceptions, a large part of agricultural waste is being used as fuel. Apart from wood, natural fibre composites are emerging with an increasing role in building industry to replace timber, steel, aluminium, concrete, etc. Composites are being used for prefabricated, portable and modular buildings as well as for exterior cladding panels. (Eisner and Travnik, 1971)

Amongst agriculture production, wheat is the second most cultivated cereal plant worldwide. Wheat straw is the main by product from cereal harvesting and often is used as fuel, cattle feed, mulch, and bedding materials for animals (Sampathrajan et al. 1992). Wheat straw has potential for manufacture of a number of board products, including a substitute for high quality interior composite board, a medium density fibreboard type product and structural composite board. (Bach, 1999).

Burning wheat straw also causes environmental problems such as air pollution, soil erosion, and a decrease in soil biological activity. Therefore, industrial utilization of agricultural residues not only prevents air pollution due to burning of residues, which adversely affect air quality and human and environmental health, but is also economically profitable for farmers. Straw could be available in very large amounts to new industrial applications. Amongst these, the production of composite board panels that are at present almost exclusively produced from wood or wood by-products seems feasible. Low-density straw panels have already been suggested for applications in thermal and acoustic insulations. (Cheng et al. 2006)

Til (*sesamum indicum*) is an annual plant growing 1.6 to 3.3 ft tall. Til is one of the most cultivated cereal plants in the world. Its stick is the main by product from cereal harvesting and often is used as fuel. *Sesamum indicum* is the cultivated type, originated in India. (Smith, Albert 1995).Sesame is very drought-tolerant, in part due to its extensive root system. However, it requires adequate moisture for germination and early growth. Moisture levels before planting and flowering impact yield most. (Bedigian, 1984).

The total global harvest was about 3.84 million metric tons of sesame seeds in 2010. The top three producers, Burma, India, and China, accounted for 50 percent of global production. The waste material of til is 2-3 times greater than the seed production (FAO U.S 2012).So there is a huge possibility of getting til residue as raw material for composite board manufacturing.

1.2 Objective of the Study

The objectives are-

- To study the physical and mechanical properties of Til (*sesamum indicum*) and Til, Wheat straw combined composite board.
- To utilize Til (*sesamum indicum*) and Wheat straw (*Tritcium aestivum*) as alternate source of raw material for composite board manufacturing.

Chapter Two: Review of Literature

2.1 General Information about composite board

2.1.1 Composite

Composite consist of two or more distinct constituents or phases, which when married together result in a material with entirely different properties from those of the individual components. (Paul et al. 2006). Typically, a man- made composite would consist of a reinforcement phase of stiff, strong material, frequently fibrous in nature, embedded in a continuous matrix phase. The latter is often weaker and more compliant than the former. Two of the main functions of the matrix are to transmit externally applied loads, via shear stresses at the interface, to the reinforcement and to protect the latter from environmental and mechanical damage. (Matthews et al. 1994). The advantage of such a coupling is that the high strength and stiffness of the fibres (which in most practical situations would be unable to transmit loads) may be exploited.

Composites have found commercial success in exterior applications. Scientific investigations of these materials have concentrated, mainly, on improving mechanical properties. composites may have good rot resistance, few scientific studies on the biodegradation of these materials have been carried out. Laboratory procedures for evaluating the decay resistance of wood products are common but they are not without problems because they are more severe than most above ground field exposure tests. Also some tests may be unsuitable for composites. The main concerns are the unknown impact of the differences between solid wood and composites with regard to decay, susceptibility to moisture gradients and increased surface area to volume ratio of composite panel products. (Wolcott and Englund, 1991)

2.1.2 Composite board

Composite boards are not more than a few decades old productions. In early 1920's, first unsuccessful efforts were made for manufacturing composite board as for the lack of suitable adhesives. In 1930's, new techniques were introduced for resin application which smoothed the path of particle production in the 1940's (Moslemi, 1985). High quality composite board products are now available in industrial level for satisfying consumer demands.

Wood composite or lingo-cellulosic materials are bonded with suitable synthetic resin with the help of suitable temperature and pressure to constitute a composite board (Anon, 1970). Typically, composite board is made in layers. The face layer of particleboard consists of fine wood particles and core layer comprises coarse particles. The result is a smoother surface for laminating, overlaying, painting or veneering. Composite board is produced in a variety of sizes and density which supply a huge opportunity to design ultimate products of specific particleboard needed. Composite board is widely used as house construction, interior decoration, furniture manufacturing, floor, desk or counter tops and office dividers (Wang and Sun, 2002).

2.1.3 Raw Materials for composite board

2.1.3.1 Ligno-cellulosic Materials

i. Sawmill residues, such as slabs, edging, trimming etc. Planer shavings
ii. Planer shavings
iii. Residues from timber cutting in furniture and cabinet manufacturing plants
iv. Residues from match factories
v. Veneer and plywood plant residues
vi. Sawdust logging residues, such as short logs, broken logs, crooked legs, small tree tops and branches, forest thinning etc.
vii. Bark

2.1.3.2 Non-woody Materials

i. Jute sticks
ii. Bagasse
iii. Bamboo
iv. Flax shaves
v. Cotton stalks
vi. Cereal straw
vii. Almost any agricultural residue after suitable treatment (Salehuddin, 1992).

2.1.4 Types of Composite/ Particleboard

2.1.4 .1. Types of Particle Used

Flake board: Particleboard in which the wood is largely in the form of flakes, giving the surface a characteristic appearance (Anon, 1970).

Chip board: A particleboard made from chips. It is made in varying thickness and may be surfaced with paper, veneers, plastic materials etc. (Anon, 1970).

Shaving board: A particleboard in which wood shavings are the chief constituents (Anon, 1970).

2.1.4.2 Pressing method used

Flat press process: where pressure is applied perpendicular to board surface, particles generally falling flat along the plane of the board surface.

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.

Moulding process: where products are molded into the desired shape with heat and pressure by using specially constructed molds or dies (Anon, 1970).

2.1.4.3 Particle size distribution in the thickness of board

i. Single layer or homogeneous board.
ii. Three layer boar5d, where coarse particles in the core layer are sandwiched between fine particles in the face layer
iii. Multi-layer or graduated board, with a graduation of ranging from the finest in the face layer to the coarsest in the core (Anon, 1970).

2.1.4.4. Density of the Composite /Particleboard

i. Low density particleboard (below 590 kg/m^3)
ii. Medium density particleboard (590-800 kg/m^3)
iii. High density particleboard (above 800 kg/m^3)

2.1.4.5 Exposure or service condition

For indoor uses, where exposure to water or high humidity does not occur and urea formaldehyde (UF) resin is used as the binder.

For exterior use, phenol-formaldehyde (PF) resin is generally used though melamine formaldehyde (MF) resin is used where the dark color of the PF resin is unwarranted.

UF resin fortified with MF resin may be used exposure is not very severe.

Exterior particleboards may be classified into structural and non-structural boards.

2.1.5 Uses of Particleboard/ Composite

Particleboard is used widely as furniture, shelves, cabinet, wall cases, benches, bookcases, kitchen cabinet, table tops, stair trends, home construction, speakers, vanities, interior signs, work surface of offices, educational establishment and other industrial products (Anon, 1997).

2.1.6 Advantages of Particleboard

i. Particle / Composite boards 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 materials, make products with unique properties and can tailor products for particular end- use.

ii. The characteristic defects thought-out the particleboard during manufacturing. Thus ensure not occurring defects during service condition.

iii. The variation in strength and stiffness due to anisotropy in wood is largely overcome as also the differential change in dimension due to absorption and desorption of moisture along or across the grain of wood.

iv. By using different species and adhesives, or particles of different size and geometry, particleboard may be manufactured suitable for exposure to weather, for interior use, for interior paneling, for exterior sideboards, for load bearing flooring purpose and so on.

v. Perhaps the most important advantage of particleboard is that it can be made in large dimensions.

2.1.7 Adhesion

Generally adhesion is the adhesive power of adjacent molecules. This adhesive power can only be developed if the molecules are sufficiently close together (distance below 3×10^{-8} cm). In this proximity molecules can interact. For solid bodies such an extremely small distance between the molecules of two parts is nearly impossible to achieve since even surface after lapping is irregular and are contaminated by oxidization, humidity and dust.

In practice adhesion is affected by the use of liquid glues which can adapt to the profile of the surface due to their rheological behavior. At present all technical procedures of gluing solid bodies use liquid glues. They wet the surface to be glued and they form glue joints after having been set or hardened. Even glue films and contract stickers during the gluing process are liquid or have a quasi-liquid phase.

2.1.8 Adhesive

Adhesives are the materials used in the fabrication of timber structures and components offers a net and efficient method of bonding together the separate pieces of wood, or of board products such as plywood, chipboard, or fiber board, which comprise the finished product. The bond attained must meet the strength requirements for the structure as a whole and this bond must remain unaffected by the condition to which it will be exposed throughout its life.

2.1.8.1. Types of Adhesive

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

2.1.8.1.1 Natural Adhesive

Adhesives of natural-origin such as animal, casein, soybean, starch and blood glues are still being used to bond wood in some plants and shops, but are being replaced more and more by synthetics. Animal glue is probably the natural adhesive most widely used, although casein glue is being used a great deal for structural laminating.

2.1.8.1.2 Synthetic Adhesive

A synthetic origin adhesive is called synthetic adhesives. Synthetic adhesives can be categorized into two groups, namely thermosetting and thermoplastic adhesives.

2.1.8.1.3 Thermosetting Adhesives

This type of adhesives is usually based on formaldehyde and set very hard and become impervious to boiling water, steam or dry heat, micro-organic attack or fungal attack and are used extensively for weather and boil proof bonds and for all exterior grade and marine plywood manufacture. The main advantage of thermosetting types is that they can be used with confidence as structural, load-bearing adhesive.

2.1.8.1.4 Thermoplastic Adhesives

Thermoplastic adhesives are fusible, soluble and poor heat and creep resistant. They are normally used for low/medium load assemblies under reasonable service conditions In general,thermoplastic adhesives have low/medium shear strength and suffer from creep at high loading. They have good resistance to oils but poor resistance to water. Thermoplastic adhesives include polyvinyl acetate (PVA), polyvinyl alcohol (PVA), polyacrylates, polyester acrylics, acrylic solvent cement, cyanoacrylates (superglue), silicone resins, polyamides and acrylic acid diesters. Over the last 35 years, properties of thermoplastic adhesives have been enhanced by toughening such that variants are available suitable for structural duties. There is widespread use of thermoplastic adhesives (anaerobic) adhesives for radial fit assemblies, and screw locking assemblies.

2.2 General Information of Til (*Sesamum indicum* .)

2.2.1 Description

Til (*Sesamum indicum* .) is one of the oldest crops in the world, and is under cultivation in Asia for over 5000 years (Bisht et al. 1998). The crop has early origins in East Africa and in India (Nayar and Mehra, 1970; Bedigian, 2003). Some reports claim sesame was cultivated in Egypt during the Ptolemiac period while others suggest the New Kingdom (Dolores et al. (2004).today, India and China are the world's largest producers of sesame, followed by Myanmar, Sudan, Uganda, Nigeria, Pakistan, Tanzania, Ethiopia, Guatemala and Turkey.

It is an annual plant growing 50 to 100 cm (1.6 to 3.3 ft) tall, with opposite leaves 4 to 14 cm (1.6 to 5.5 in) long with an entire margin; they are broadly anceolate, to 5 cm (2 in) broad, at the base of the plant, narrowing to just 1 cm (0.4 in) broad on the flowering stem.

The size, form and colours vary with the thousands of varieties now known. Typically, the seeds are about 3 to 4 millimeters long by 2 millimeters wide and 1 millimeter thick. The seeds are ovate, slightly flattened and somewhat thinner at the eye of the seed (hilum) than at the opposite end. The weight of the seeds are between 20 and 40 milligrams. (Cauvain et al. 2003). The seed coat (testa) may be smooth or ribbed.

Sesame seeds come in many colours depending on the cultivar harvested. The most traded variety of sesame is off-white coloured. Other common colours are buff, tan, gold, brown, reddish, gray and black.

Sesame seed is sometimes sold with its seed coat removed (decorticated). This is the variety often present on top of buns in developed economic (Neill, Richard. 2002)

World production fluctuates due to local economic, crop production disturbance and weather conditions. In Vietnam, sesame is known as the king of oil seeds due to the high oil content (50 – 60%) of its seed. The crop is highly drought tolerant, grows well in most kind of soils, regions and is well suited to different crop rotations. In reality, sesame is mostly grown under moisture stress with low management input by small holders (Cagrgan, 2006).

Fig: Til plant

2.2.2 Scientific classification:

Kingdom: Plantae

Subkingdom: Angiosperms

Phylum: Eudicots

Class: Asterids

Order: Lamiales

Family: Pedaliaceae

Genus: Sesamum

Species: ***S. indicum***

Binomial name *Sesamum indicum L*

2.2.3 Cultivation

Sesame is very drought-tolerant, in part due to its extensive root system. However, it requires adequate moisture for germination and early growth. While the crop survives drought as well as presence of excess water, the yields are significantly lower in either condition. Moisture levels before planting and flowering impact yield most. (Bedigian, 1984).

Most commercial cultivars of sesame are intolerant of water-logging. Rainfall late in the season prolongs growth and increases high harvest-shattering losses. Wind can also cause shattering at harvest.

Initiation of flowering is sensitive to photoperiod and to sesame variety. The photoperiod also impacts the oil content in sesame seed; increased photoperiod increases oil content. The oil content of the seed is inversely proportional to its protein content.

Sesame varieties have adapted to many soil types. The high yielding crops thrive best on well-drained, fertile soils of medium texture and neutral pH. However, these have low tolerance for soils with high salt and water-logged conditions. Commercial sesame crops require 90 to 120 frost free days. Warm conditions above 23 °C (73 °F) favor growth and yields. While sesame crops can grow in poor soils, the best yields come from properly fertilized farms. (Diamond J, 1997)

2.2.4 Processing

After harvesting, the seeds are usually cleaned and hulled. In some countries, once the seeds have been hulled, they are passed through an electronic colour-sorting machine that rejects any discolored seeds to ensure perfectly coloured sesame seeds. This is done because sesame seeds with consistent appearance are perceived to be of better quality by consumers, and sell for a higher price. Immature or off-sized seeds are removed and used for oil production.

2.2.5 Pests

Sesame is used as a food plant by the larvae of some Lepidoptera species, including the Turnip Moth.

2.2.6 Applications and role of Til *(Sesamum indicum).*

2.2.6.1 Production and trade

The total global harvest was about 3.84 million metric tons of sesame seeds in 2010. The largest producer in 2010 was Burma (Myanmar), and the top three producers, Burma, India, and China, accounted for 50 percent of global production. (FAO U.S 2012). The global average yield of sesame seeds was 0.49 metric tons per hectare in 2010. The table in this section presents the 2010 production (million metric tons) and yields (metric tons per hectare) for the top ten producer countries.

The most productive sesame seed farms in the world were in the European Union with an average composite yield of 5.5 metric tonnes per hectare in 2010; Italy reported the best nationwide average yield of 7.2 metric tonnes per hectare. There is a large yield gap and farm loss differences between major sesame seed producers, in part because of knowledge gap, poor crop management practices and use of technology.

The white and other lighter coloured sesame seeds are common in Europe, the Americas, West Asia, and the Indian subcontinent. The black and darker coloured sesame seeds are mostly produced in China and southeast Asia. Africa produces a variety of sesame seeds.

Beginning in the 1950s, U.S. production of the crop has been largely centered in Texas, with acreage fluctuating between 10,000 to 20,000 acres (40 to 80 km^2) in recent years. The country's crop does not make up a significant global source; indeed imports have now outstripped domestic production.

2.2.6.2 Trade

The world traded over a billion dollars worth of sesame seeds in 2010. The trade volume has been increasing rapidly in the last two decades.

Japan is the world's largest sesame importer. Sesame oil, particularly from roasted seed, is an important component of Japanese cooking and traditionally the principal use of the seed. China is the second largest importer of sesame, mostly oil-grade sesame. China exports lower priced food grade sesame seeds, particularly to Southeast Asia. Other major importers are the United States, Canada, Netherlands, Turkey and France.

2.2.6.3 Traditional and Alternative Medicinal Uses

In the ancient Arab world, people used to have balls made of dry breadcrumbs, dates, almonds, and pistachios, moistened with a few spoonful of sesame oil and coated with sesame seeds before going out for a carvan which would sustain them through the hot, dry desert and offer nutritional value as well. This handy old recipe makes ideal present-day back packing Indian ayurvedic medicine. It is rubbed into the skin during abhyanga, a form of Indian massage which improves the flow of energy and helps to remove the impurities from the body. The oil is also used as an

Ant bacterial agent in preparations of mouthwash which prevents against tooth and gum diseases.

Sesame oil also has a reputation as a sedative in Indian and Tibetan medicine. It can be used to relieve anxiety and insomnia by applying a few drops directly into the nostrils. Its calming effects are supposedly carried to the brain by way of blood vessels in the nose. In Chinese System of Medicine, dry flowers are used in curing alopecia, frostbite and constipation. (Hu, Y.M., Ye, W.C., Yin, Z.Q., Zhao, S.X.).

2.2.6.4 Soap production from Sesame seed oil

Archeological reports from Turkey indicate that sesame was grown and pressed to extract oil at least 2750 years ago in the empire of Urartu. (Hancock, James F. 2004) .A simple technology for the Production of Soap from Northern Nigerian Sesame (Sesamum indicum,L.) Seed oil was reported by Warra (2011). This is in line with the cold-process alkali hydrolysis which is a simple adoptable technology reported by (Warra et al. 2009a) and (Warra et al. 2009b).

2.2.7 Table 1: Fibre Length and Chemical Properties of Selected Non-Wood and Wood Materials (Atchison, 1993, Mabee and Roy 1999)

Source	Average FibreLength (mm)%	Cellulose%	Lignin%	Hemicellulose%	Ash %	Silica%
Wheat Straw	1.5	50-52	16-20	26-30	5-10	4-8
Til	1-1.5	47-51	23	25	5	-
Barley Straw	-	47-48	14-15	24-29	5-7	3-6
Rye Straw	-	44-53	16-19	27-30	2-5	0.5-4
Bagasse	1.7	53-56	19-24	27-32	2-5	2-4
Rice Straw	0.5-1	42-46	12-15	24-30	15-20	10-18
Kenaf Bast	2.6	47-57	15-19	23	1.7-5	-

2.3 General Information of Wheat (*Triticum aestivum.)*

2.3.1 Description

Wheat (*Triticum aestivum.*) is a cereal grain, originally from the Levant region of the Near East and Ethiopian Highlands, but now cultivated worldwide. In 2010, world production of wheat was 651 million tons, making it the third most-produced cereal after maize (844 million tons) and rice (672 million tons) World Wheat Crop To Be Third Largest Ever." (Farmers Weekly, 2010).

This grain is grown on more land area than any other commercial food. World trade in wheat is greater than for all other crops combined. Globally, wheat is the leading source of vegetable protein in human food, having a higher protein content than other major cereals, maize (corn) or rice. In terms of total production tonnages used for food, it is currently second to rice as the main human food crop and ahead of maize, after allowing for maize's more extensive use in animal feeds. In low rainfall areas, better use of available soil-water (and better control of soil erosion) is achieved by retaining the stubble after harvesting and by minimizing tillage. (Kiss et al. 2012).

Wheat was a key factor enabling the emergence of city-based societies at the start of civilization because it was one of the first crops that could be easily cultivated on a large scale, and had the additional advantage of yielding a harvest that provides long-term storage of food. Wheat contributed to the emergence of city-states in the Fertile Crescent, including the Babylonian and Assyrian empires. Wheat grain is a staple food used to make flour for leavened, flat and steamed breads, biscuits, cookies, cakes, breakfast cereal, pasta, noodles, couscous and for fermentation to make beer, other alcoholic beverages or bio fuel (Cauvain et al. 2003)

Wheat is planted to a limited extent as a forage crop for livestock, and its straw can be used as a construction material for roofing thatch. The whole grain can be milled to leave just the endosperm for white flour. The by-products of this are bran and germ. The whole grain is a concentrated source of vitamins, minerals, and protein, while the refined grain is mostly starch. In the Punjab region of India and Pakistan, as well as North China, irrigation has been a major contributor to increased grain output. More widely over the last 40 years, a massive increase in fertilizer use together with the increased availability of semi-dwarf varieties in developing countries has greatly increased yields per hectare. However, farming systems rely on much more than fertilizer and breeding to improve productivity. A good illustration of this is Australian wheat growing in the southern winter cropping zone, where, despite low rainfall (300 mm), wheat cropping is successful even with relatively little use of nitrogenous fertilizer. This is achieved by 'rotation cropping' (traditionally called the levy system) with leguminous pastures and, in the last decade, including a canola crop in the rotations has boosted wheat yields by a further 25%. In these low rainfall areas, better use of available soil-water (and better control of soil erosion) is achieved by retaining the stubble after harvesting and by minimizing tillage. (Kiss et al. 2012).

2.3.2 Scientific classification:

Kingdom: Plantae

Subkingdom: Angiosperms

Phylum: Monocots

Class: Commelinids

Order: Poales

Family: Poaceae

Genus: Triticum

Species: *T. aestivum*

Binomial name : ***Triticum aestivum L***

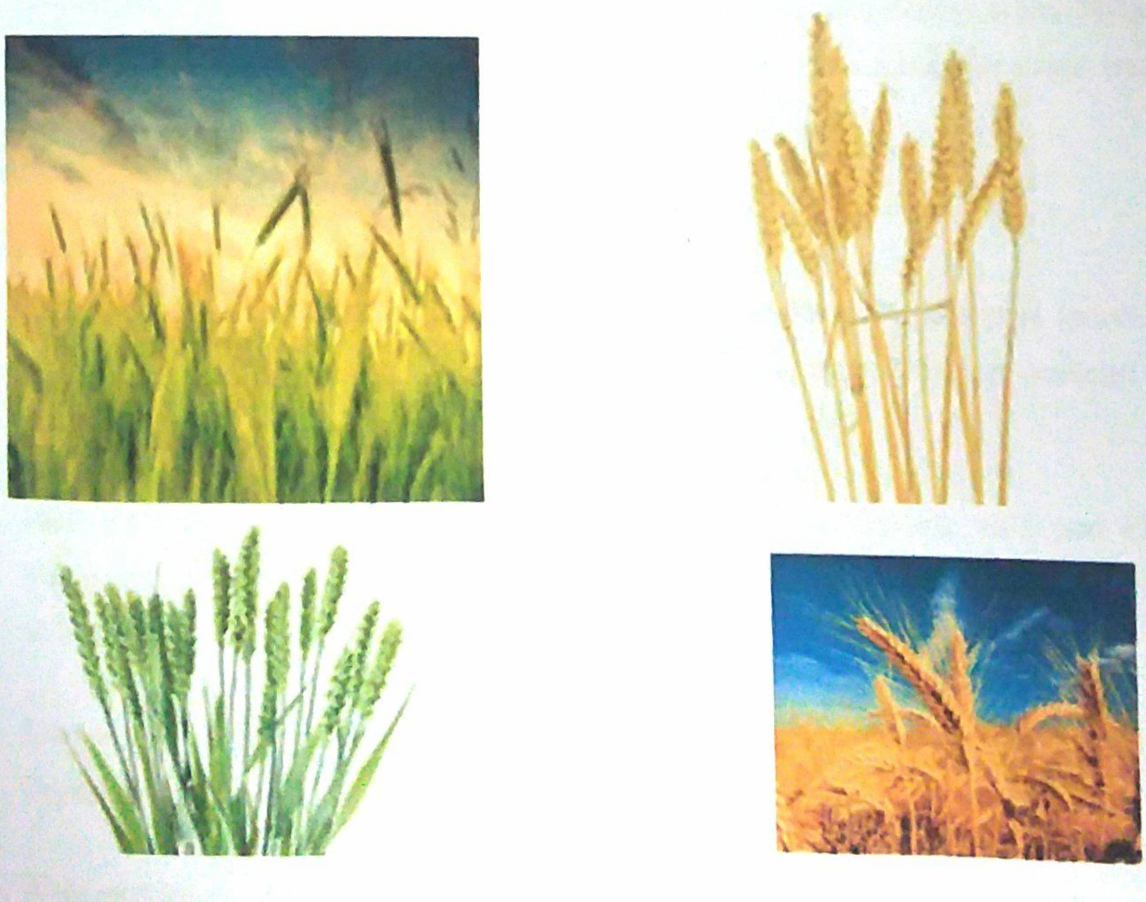


Fig: wheat plant

2.3.3 Crop development

Wheat normally needs between 110 and 130 days between sowing and harvest, depending upon climate, seed type, and soil conditions (winter wheat lies dormant during a winter freeze). Optimal crop management requires that the farmer have a detailed understanding of each stage of development in the growing plants. In particular, spring fertilizers, herbicides, fungicides, and growth regulators are typically applied only at specific stages of plant development. For example, it is currently recommended that the second application of nitrogen is best done when the ear (not visible at this stage) is about 1 cm in size. Knowledge of stages is also important to identify periods of higher risk from the climate. For example, pollen formation from the mother cell, and the stages between anthesis and maturity are susceptible to high temperatures, and this adverse effect is made worse by water stress.(Slafer GA, Satorre, 1999) Farmers also benefit from knowing when the 'flag leaf' (last leaf) appears, as this leaf represents about 75% of photosynthesis reactions during the grain filling period, and so should be preserved from disease or insect attacks to ensure a good yield.

Several systems exist to identify crop stages, with the Feekes and Zadoks scales being the most widely used. Each scale is a standard system which describes successive stages reached by the crop during the agricultural season.

2.3.4 Diseases

Seed-borne diseases: these include seed-borne scab, seed-borne Stagonospora (previously known as Septoria), common bunt (stinking smut), and loose smut. These are managed with fungicides.

Leaf- and head- blight diseases: Powdery mildew, leaf rust, Septoria tritici leaf blotch, Stagonospora (Septoria) nodorum leaf and glume blotch, and Fusarium head scab.(Gautam et al. 2012).

Crown and root rot diseases: Two of the more important of these are 'take-all' and Cephalosporium stripe. Both of these diseases are soil borne.

Stem rust diseases: Caused by basidiomycete fungi

2.3.5 Pests

Wheat is used as a food plant by the larvae of some Lepidoptera (butterfly and moth) species including The Rustic Shoulder-knot, Setaceous Hebrew Character and Turnip Moth. Early in the season, many species of birds, including the Long-tailed Widowbird, and rodents feed upon wheat crops. These animals can cause significant damage to a crop by digging up and eating newly planted seeds or young plants. They can also damage the crop late in the season by eating the grain from the mature spike. Recent post-harvest losses in cereals amount to billions of dollars per year in the USA alone, and damage to wheat by various borers, beetles and weevils is no exception. Rodents can also cause major losses during storage, and in major grain growing regions, field mice numbers can sometimes build up explosively to plague proportions because of the ready availability of food. To reduce the amount of wheat lost to post-harvest pests, Agricultural Research Service scientists have developed an "insect-o-graph," which can detect insects in wheat that are not visible to the naked eye. The device uses electrical signals to detect the insects as the wheat is being milled. The new technology is so precise that it can detect 5-10 infested seeds out of 300,000 good ones.(USDA Agricultural Research 2010) Tracking insect infestations in stored grain is critical for food safety as well as for the marketing value of the crop

2.3.6 Applications and role of Wheat (*Triticum aestivum.)*

2.3.6.1 Fermentation industry

Synthetis and expensive substrates are being replaced by agro-industrial by-products for the production of a wide range of value added biotechnological products (Pandey, 1992; Raimbault, 1998; Mojsov, 2010). Filamentous fungi can efficiently use these by-products (Pandey et al. 1999; Singh et al. 2009; Mojsov, 2010). WS is an efficient substrate due to its better air circulation, loose study binding ability and efficient penetration by fungal mycelium. It is the cheaper substrate so it is a cost effective substrate in fermentation industry. Extracellular hydrolytic enzymes are being produced using WS under Sub-merged Fermentation (SF) as well as Solid-State Fermentation (SSF) systems. A large number of secondary metabolites can also be obtained by fermentation of WS (Yasin et al. 2010).

2.3.6.2 Study and pulp industry

Nonwood fibers containing cellulose and hemicellulose have a long history as a raw material in study and pulp industry (Singh et al. 2009). Straw and grasses are thus being utilized in larger amounts in this industry. Wheat straw can be easily pulped and bleached with about 40% yield and producing fine textured study (CWC and Domtar Inc. 1997). Cellulases and hemicelluloses' enzymes have central application for bio bleaching and production of dissolving pulp. The biosynthesis of these enzymes takes place using different cellulosic substrates including wheat bran, wheat straw etc.(Gubitz et al. 1998), (Bajpai,1999) and (Singh et al. 2009).

2.3.6.3 Bioremediation

Bioremediation has the potential to restore contaminated environments at no expense. Treatment of wastewater through safer methods has always been the focus of environmentalists using various microbial and plant species (Javed et al. 2012). However, degradation of heavy metals has been a question mark for human being. Wheat straw, an abundantly available source is reported for sorption of heavy metals i.e. chromium. It is a very cheap and flexible substrate for metal ions. Functional groups like hydrolytic, carboxylic and phenolic groups in the lignin, cellulose and fatty acid units are ideal for ion fixation (Dupont et al. 2003).

2.3.6.4 Soil fertility and organic content

Crops grow by utilizing the minerals from soil. When crops are harvested the minreal contents of the soil are also lost and thus the supplementation of synthetic fertilizers is required. To provide a substitute for that organic wastes or agricultural wastes can be added to soil to fulfill the demand of crops. Wheat straw a major staple crop is harvested on a massive scale every year and the residues are helpful in maintaining the soil fertility if added as such or by mixing with the urea to balance the nitrogen content in the field (Murray and Bruehl, 1983).

2.3.6.5 Medicinal value

Wheat straw has been reported to relief from condition of biliousness (Drankham et al. 2003). It has been suggested that tooth disorders i.e. Pyorrhea can be prevented and cured using wheat straw. Chewing of wheat grass not only benefits by exercising of teeth and gums but also assists in digestion. It acts as brilliant mouth wash especially for sore throat and pyorrhea as well as it keeps tooth from decay and tooth aches. Moreover, it extracts out toxins from the gums and hence controls bacterial growth (Kumar et al. 2011). With dermatological context the ash of wheat straw has been reported to remove skin blemishes (Drankham et al. 2003).

2.3.6.6 Making biochar

Biochar is technically considered as most feasible way of creating carbon sink as well as for improving soil structure to enhance the productivity of soils about 2-3 times. The peculiar structure of biochar offers large surface area which is important in improving the soil texture, arability, retention of nutrients and provides surface for growth of beneficial microorganisms. Moreover the water holding capacity of soils is also increased by adding biochar to them, thus helps prevent leaching of valuable nutrients into streams and rivers (Goodall, 2010).

Chapter Three: Materials and methods

3.1 Manufacturing of Composite Boards

3.1.1 Experimental Design

Some physical and mechanical properties were evaluated from Composite board made from Til *(sesamum indicum)* and Wheat straw (*Tritcium aestivum).* The UF 15% were used to manufacture two types of board respectively in the laboratory of Forestry & Wood Technology Discipline, Khulna University, Khulna, Bangladesh. The required Temperature, Pressure and Time shown in table-3.1.

Table 3.1 UF ratio, Temperature, Pressure and Time of two type's board shown in table-3.1.

Composite Types	Formulation	Temperature	Pressure	Time
Composite board from Til (sesamum indicum)	UF 15%	150°C	5MPa	6min+12min
Com posite Board from Til (sesamum indicum) and Wheat straw (Tritcium aestivum) mixture (50:50)	UF 15%	150°C	5MPa	6min+12min

3.1.2 Collection of Raw Materials

Til *(sesamum indicum)* and Wheat straw (*Tritcium aestivum*) are collected from the farmers as raw material for the manufacturing of Composite board. For the purpose of preparing samples Til and Wheat straw are chipped by chopper machine. After chipping, the chips are run into grinder machine, by which the chips turned into particle. In this study the size of Particle ranges <2mm is used. The Urea-Formaldehyde is collected from local market, which is available as raw material.

3.1.3 Preparation of Raw Materials

To obtain particle-boards with good strength, smooth surfaces, and equal swelling, manufacturers ideally using a homogeneous material with a high degree of slenderness (long, thin particles), no over-size particles, no splinters, and no dust is needed

3.1.4 Screening

For the purpose of preparing samples the til stacks and wheat straw were screened through a mesh screen to separate the dust, chipped individually by using traditional hand tools. Subsequently, the til stacks and wheat straw chips were converted separately into particle with a grinder by using a screen opening at 4.5 mm. particles were individually screened through 2 mm and 1.5 mm.

3.1.4 Drying of Raw Materials

Later than processing, the raw materials were dried in an electrically heated lab scale oven at 103±3°C for 24 hours.

3.1.5 Mat Formation

After drying the particles were mixed manually with Urea Formaldehyde (UF) resin. Based on oven dry particle weight 15% UF were applied respectively for both type of board. No additives were used in panel manufacturing. Ammonium chloride was used as curing agent amount 1%. Hand performed mats were formed on a steel sheet. For producing 10 mm particleboard, the average mat thicknesses were 40 mm.

3.1.6 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 5 MPa pressure for 6 minutes. The temperature switch was switched off after 6 minutes and every board was retained another 12 minutes under pressure. Two types of board with six treatments were manufactured in the same way.

3.1.7 Finishing of Manufactured board

3.1.7.1 Trimming

The boards were then trimmed by hand saw to reduce edge effects on the properties of particleboard. The boards were conditioned for two weeks at room temperature previous to tests.

3.1.7.2 Sanding

The trimmed boards were sanded with 80 grade sand paper with rough sanding maching.

3.1.2 Flow Diagram of Composite Board Manufacturing Process

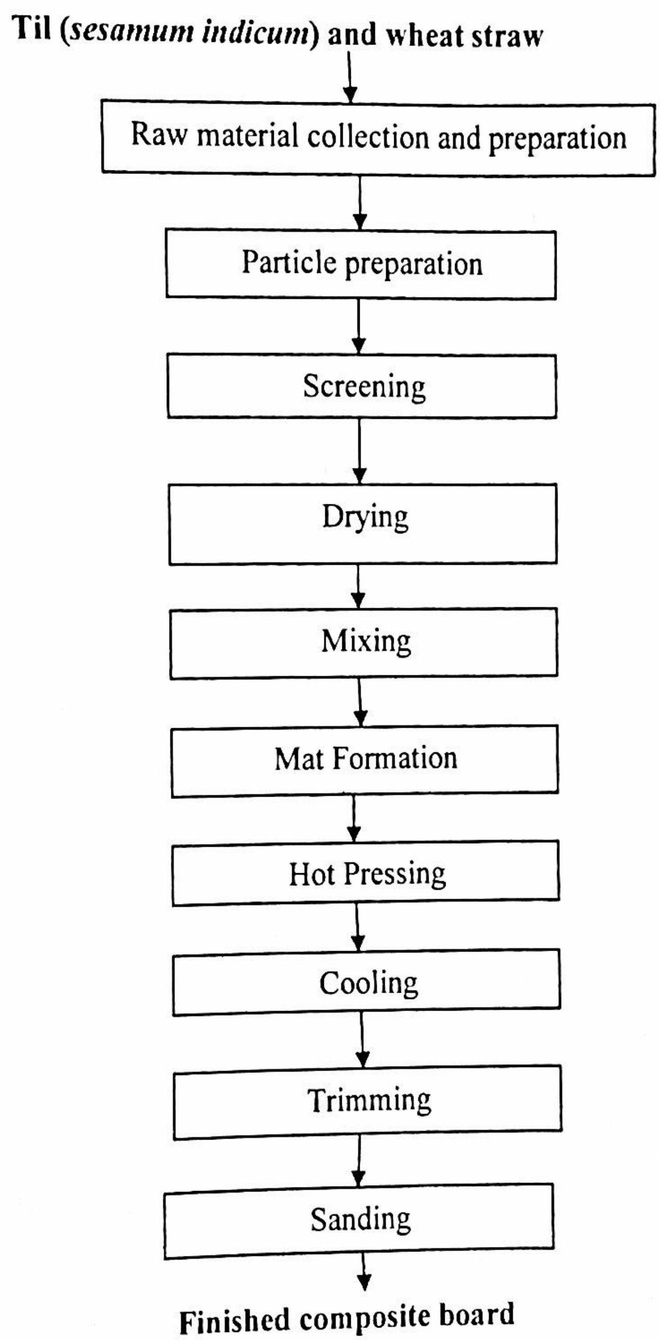


Fig. 3.1: Flow Diagram of Composite Board Manufacturing Process

Fig:Til board

Fig: Til+Wheat straw board

3.2 Laboratory Test

For evaluating physical and mechanical properties eighteen samples were collected from each board. Some samples with an average dimension of 50 mm × 30 mm were collected for testing the physical properties. Remaining specimens with 150 mm × 30 mm average dimension were collected for MOE and MOR test. The specimens were collected and tested according to ASTM standard. (ASTM, 1999).

3.3 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.

3.3.1 Modulus of Rupture (MOR)

Modulus of Rupture (MOR) is measured by the University Testing Machine (UTM), Model no: UTM-100. MOR was calculated by the following formula-

$$MOR = \frac{3pl}{2bd^2} \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

3.3.2 Modulus of Elasticity (MOE)

Modulus of Elasticity (MOE) is measured by the University Testing Machine (UTM), Model no: UTM-100. MOE is calculated by the following formula-

$$MOE = \frac{pl^3}{4\Delta bd^3} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, p = load in N, l = span length in mm, b = width of the test specimen in mm, d = thickness of test specimen in mm and Δ = deformation of the board in mm.

3.4 Determination of Physical Properties

All the samples are cut into (50mm × 30 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= $\frac{\text{Weight of Wood}}{\text{Standard Volume}}$

3.4.2 Moisture Content = $\frac{\text{Green Weight} - \text{Oven Dry Weight}}{\text{Oven Dry Weight}} \times 100$

3.4.3 Water absorption:

Water absorption is calculated by the following formula-

$$Aw = \frac{m2 - m1}{m1} \times 100$$

Where,

Aw=Water absorption (%)

m1=Weight of the sample before immersion in water (gm)

m2=Weight of the sample after (24 hr) immersion in water (gm)

3.4.4 Thickness swelling:

Thickness swelling is calculated by the following formula-

$$Gt = \frac{t2 - t1}{t1} \times 100$$

Where,

Gt=Thickness swelling (%)

t1= Thickness of the sample before immersion in water (gm)

t2=Thickness of the sample after (24 hr) immersion in water (gm)

3.4.5 Linear Expansion:

Linear Expansion is calculated by the following formula-

$$LX(\%)=\frac{LA-LB}{LB}\times 100$$

Where,

LX=Linear Expansion (%)

LB=length of the sample before immersion in water (gm)

LA=length of the sample after (24 hr) immersion in water (gm)

3.5 Statistical Analysis

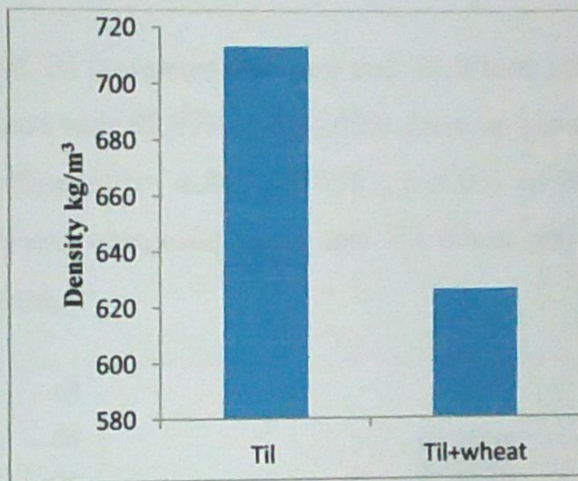
For different board properties average and standard deviation were determined. The data were analyzed with SPSS (Statistical Package for Social Science) statistical software. Analysis of variance (ANOVA) and LSD (Least Significant Difference) were carried out for determining potential difference and mean separation of the treatments at the 5 % level of significance.

Chapter four: Results and Discussion

4.1Physical properties

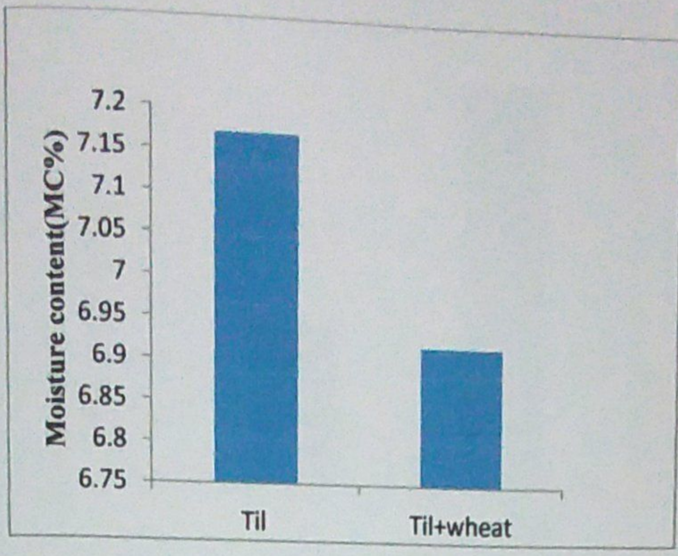
4.1.1 Density

The density of Til (*sesamum indicum*) and Til,Wheat straw (*Tritcium aestivum*) combined composite board were 713.33 kg/m^3 and 626.34 kg/m^3.From un-pared T-test, it was found that there was significant difference ($t=16.766$, $df = 18$, $p<0.05$) of density between the Til (*sesamum indicum*) composite board and Til,Wheat straw (*Tritcium aestivum*) combined composite board.



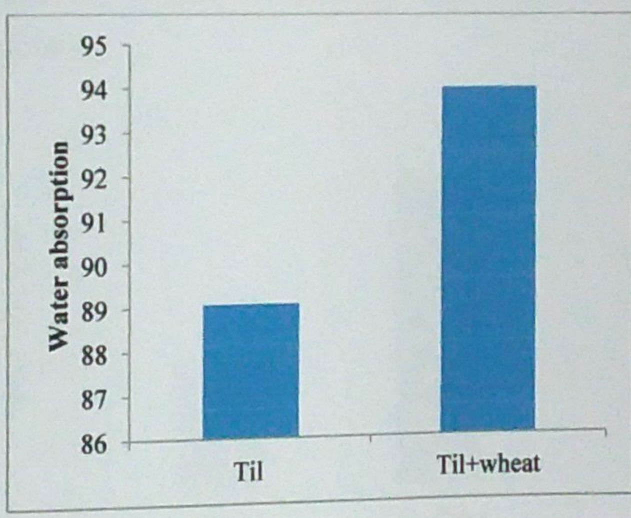
4.1.2 Moisture Content

The Moisture Content of Til (*sesamum indicum*) and Til,Wheat straw (*Tritcium aestivum*) combined composite board were 7.17% and 6.92% .From un-pared T-test, it was found that there was significant difference ($t=2.268$, $df = 18$, $p<0.05$) of Moisture Content between the Til (*sesamum indicum*) composite board and Til,Wheat straw (*Tritcium aestivum*) combined composite board.



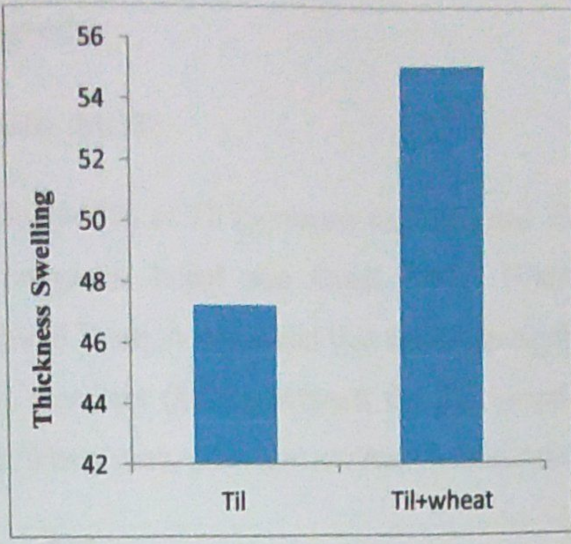
4.1.3 Water absorption

The Water absorption of Til (*sesamum indicum*) and Til,Wheat straw (*Tritcium aestivum*) combined composite board were 89.07% and 94.03% .From un-pared T-test,it was found that there was significant difference (t= -6.860 , df =18 , $p<0.05$) of Water absorption between the Til (*sesamum indicum*) composite board and Til,Wheat straw (*Tritcium aestivum*) combined composite board.



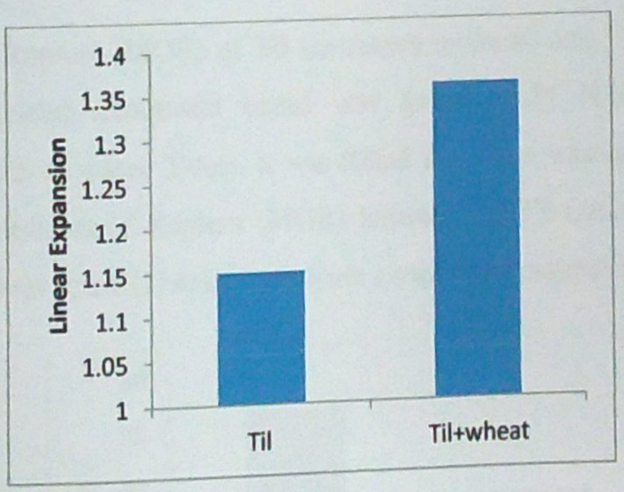
4.1.4 Thickness swelling

The Thickness swelling of Til (*sesamum indicum*) and Til,Wheat straw (*Tritcium aestivum*) combined composite board were 47.27% and 55.13% .From un-pared T-test, it was found that there was significant difference (t=-16.544 , df = 18 , $p<0.05$) of Thickness swelling between the Til (*sesamum indicum*) and Til,Wheat straw (*Tritcium aestivum*) combined composite board.



4.1.5 Linear Expansion

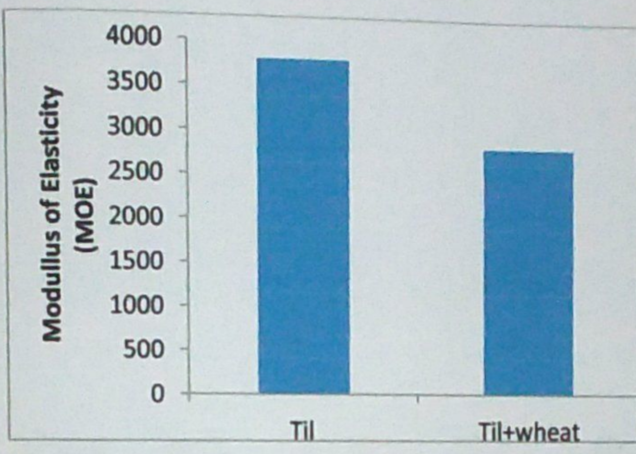
The Linear Expansion of Til (*sesamum indicum*) and Til,Wheat straw (*Tritcium aestivum*) combined composite board were 1.15% and 1.36% .From un-pared T-test, it was found that there was significant difference (t= -5.636 , df = 18 , $p<0.05$) of Linear Expansion between the Til (*sesamum indicum*) composite board and Til,Wheat straw (*Tritcium aestivum*) combined composite board.



4.2 Mechanical properties

4.2.1 Modulus of Elasticity (MOE)

The Modulus of Elasticity (MOE) of Til (*sesamum indicum*) and Til Wheat straw (*Tritcium aestivum*) combined composite board was found 3792.9 N/mm^2 and 2827.1 N/mm^2 respectively . From un-pared T-test, it was found that there was significant ($t=14.773$, $df=18$, $p<0.05$) of Modulus of Elasticity (MOE) between the Til (*sesamum indicum*) combined composite board and Til,Wheat straw (*Tritcium aestivum*) composite board.



4.2.2 Modulus of Rupture (MOR)

The Modulus of Rupture (MOR) of Til (*sesamum indicum*) and Til, Wheat straw (*Tritcium aestivum*) combined composite board was found 36.71 N/mm^2 and 28.29 N/mm^2 respectively . From un-pared T-test, it was found that there was significant ($t= 20.577$, $df = 18$, $p<0.05$) of Modulus of Rupture (MOR) between the Til (*sesamum indicum*) composite board and Til,Wheat straw (*Tritcium aestivum*) combined composite board.

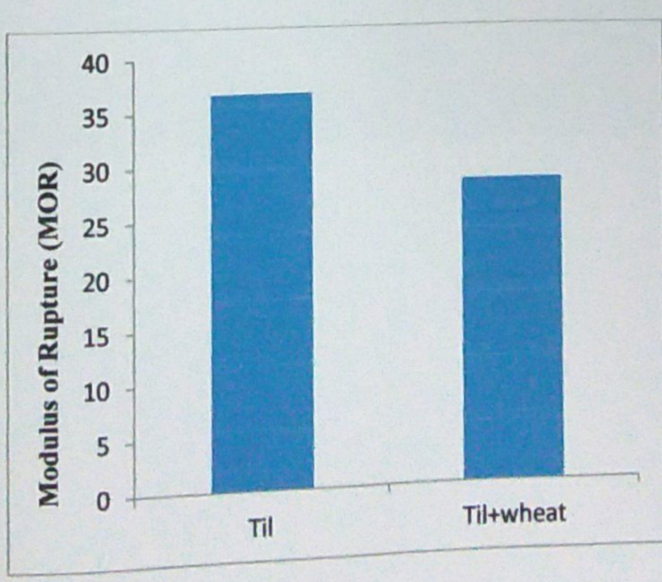


Table 4.1: Comparison of Til and Tit-Wheat straw combined board value with ANSI value.

	MOE N/mm^2	MOR N/mm^2	Density kg/m^3	Moisture Content %	Water absorption %	Thickness swelling %	Linear Expansion %
ANSI VALUE FOR MEDIUM DENSITY COMPOSITE BOARD	1900	17.50	600-800	4-9	40	40	.49
TIL BOARD VALUE	3792.9	36.71	713.33	7.17	89.07	47.27	1.15
TIL+ WHEAT STRAW BOARD VALUE	2827.1	28.29	626.34	6.92	94.03	55.13	1.36

Chapter five: Conclusion

In this research, an attempt is made to understand the mechanical and Physical properties of composite board manufactured from Til (*sesamum indicum*) and Til , Wheat straw *(Tritcium aestivum*).

Agricultural waste materials and annual plant fiber have become alternative raw materials for the production of particle or fiber composite materials. The most frequently referred alternative non-wood materials can be jute, kenaf, wheat straw and til residues .

The density of til residue and til, wheat straw combined composite board are medium according to the standard. The MOE and MOR show satisfactory and comparatively higher than the standard. As cheap, renewable source til and wheat straw can be used in medium density composite board manufacturing with comparatively high strength. As a consequence, these two types of board s require additional treatment, surface coating of the end product or water repellent treatments prior to manufacture for dimensionally stable composite board. It is also necessary to ensure even mixing of adhesives to increase internal bonding. Til residue and wheat straw may be useful and beneficial alternative source for composite board manufacturing with comparisons to the strength properties. Further research about Til and wheat straw board manufacturing can increase its use and reduce the pressure on forest for wood consumption for composite board manufacturing.

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Appendix

Table: Independent Samples Test for Density.

		Levene's Test for Equality of Variances		Independent Samples Test						
		F	Sig.	t	df	Sig.(2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Density	Equal variance assumed	1.342	.262	16.766	18	.000	1.342	.262	16.766	18
	Equal variances not assumed			16.766	14.601	.000	87.100	5.19498	16.766	14.601

Table: Independent Samples Test for Moisture Content (MC)

		Levene's Test for Equality of Variances		Independent Samples Test						
		F	Sig.	t	df	Sig.(2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Moistue Content	Equal variance assumed	1.226	.283	2.268	18	.036	.26300	.11598	.01934	.50666
	Equal variances not assumed			2.268	14.263	.039	.26300	.11598	.01469	.51131

Table: Independent Samples Test for Water absorption.

		Levene's Test for Equality of Variances		Independent Samples Test						
		F	Sig.	t	df	Sig.(2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Water absorption	Equal variance assumed	.093	.764	-6.860	18	.000	-5.00300	.72931	-6.53523	-3.47077
	Equal variances not assumed			-6.860	17.965	.000	-5.00300	.72931	-6.53544	-3.47056

Table: Independent Samples Test for Linear expansion.

		Levene's Test for Equality of Variances		Independent Samples Test						
		F	Sig.	t	df	Sig.(2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Linear expansin	Equal variance assumed	.974	.337	-5.636	18	.000	-.20900	.03708	-.28691	-.13109
	Equal variances not assumed			-5.636	16.934	.000	-.20900	.03708	-.28726	-.13074

Table: Independent Samples Test for Thickness swelling.

		Levene's Test for Equality of Variances		Independent Samples Test						
		F	Sig.	t	df	Sig.(2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Thicness swelling	Equal variance assumed	.285	.600	-16.544	18	.000	-7.88200	.47641	-8.88291	-6.88109
	Equal variance not assumed			-16.544	16.731	.000	-7.88200	.47641	-8.88838	-6.87562

Table: Independent Samples Test for MOE

		Levene's Test for Equality of Variances		Independent Samples Test						
		F	Sig.	t	df	Sig.(2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
MOE	Equal variance assumed	1.800	.196	14.773	18	.000	765.80000	51.8395	656.8921	874.7099
	Equal variances not assumed			14.773	15.704	.000	765.80000	51.8395	655.7374	875.8626

Table: Independent Samples Test for MOR.

		Levene's Test for Equality of Variances		Independent Samples Test						
		F	Sig.	t	df	Sig.(2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
MOR	Equal variance assumed	.996	.331	20.577	18	.000	7.87000	.38246	7.06648	8.67352
	Equal variances not assumed			20.577	17.368	.000	7.87000	.38246	7.06438	8.67562