ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CHEMICAL AND BIO ENGINEERING

PRODUCTION OF PARTICLE BOARD FROM COTTON STALK

A Thesis submitted to The School of Chemical and Bio Engineering partial Fulfilment of the Requirement for the award of the Degree of Master of Science in Chemical Engineering under (Environmental Engineering Stream)

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June 2018

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This is to certify that the thesis prepared by Mola Berhe, entitled: "**Production of Particle Board from Cotton Stalk "** and submitted in partial fulfilment of the requirements for the degree of Master of Science in Chemical Engineering under (Environmental Engineering) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

Signed by the Examining Committee:

Internal Examiner ______________________ Signature ____________ Date ______________

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School Dean / Graduate Program Coordinator.

DECLARETION

I declare that this thesis entitled "***Productions of Particle Board from Cotton Stalk*** " has not been submitted in any form for another degree, diploma or an award at any university or other institution of the tertiary education. Whenever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature and discussions. Information taken from published and unpublished work of others has been acknowledged in the text and a list of references is given. The work was under the guidance of ***Dr. Shegaw Ahmed*** who is an Assistant professor from Addis Ababa University, Addis Ababa institute of Technology, School of Chemical and Bio Engineering.

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ABSTRACT

Cotton stalk is a waste by-product of cotton farming and a problem of dispose or burned in open air in Ethiopia, farmers try to burn immediately, after harvesting to protect parasites such bollworm, so the stalks contributes to the emission of harmful greenhouse gases which pollute the environment. In this study, cotton stalk collected and particle board (CSPB) was produced with adhesives of urea formaldehyde using factors hot pressing time, temperature and varying resin contents with hydraulic mechanical manually pressing operations. At first the cotton stalk was analyzed using the ASTM method its morphological structure, proximity and chemical compositions was determined to compare with hard wood characteristics and has good properties. Then cotton stalk particle board (CSPB) was produced using 21 cm by 21 cm mould for mat forming and the ratio of the coarse(1-1.8)mm and fin (2-3.5)mm particle size and ratio was 60:40 wt. % respectively. Effects of operating parameters were tested using universal testing machine on the physical and mechanical properties. The cotton stalk board was examined, results for modules of strength (MOR) 11.58 MPa and modules of elasticity in in bending (MOE) 2273 MPa and internal bond (IB) 0.58 MPa respectively. The physical properties thickness swelling (TS) and water absorption (WA) were tested using water bath. The average result were TS 69.7, 75.4 % And WA 122.7, 129.7 wt. % for 2 and 24 hour immersion time. In order to obtain optimal quality boards compering to standards. The optimal physical and mechanical properties were obtained at a pressing temperature of 150 °C for 10 min with 11 % resin content of urea formaldehyde at constant operation pressure 15 MPa and target density of 0.75g/cm^3 with hot pressing. CSPB with urea formaldehyde blend adhesive has comparable mechanical properties to the fabricated board form hard woods. So, it has potential to serve as alternative row materials for particle board productions.

AKNOWLEDGMENTS

I would like to thank the Almighty GOD for giving me the strength and wisdom to successfully complete this Thesis for his defense and strength, and an ever present helps in the entire situation and challenge that I face. Moreover, I would like to express my heartfelt appreciation and thank to my Instructors and **this Thesis Research Supervisor Dr. Shegaw Ahmed**, for his sustainable and appreciable guidance, tireless advising, and sharing his knowledge, skill, experience. And I also like to express my gratitude to Ethiopian forest and Environment Institute Research Center staffs for their support to carry out experimental works; Chemical and Mechanical Engineering department laboratory staffs. Additionally, I want to thank to Maychew particle board share company quality control department staff workers for all, for their effort less help, and also for Werrer Agricultural Research Center, for the raw material acquirement; and my deepest gratitude also goes to my best friends especially Ato Muleta Sharew, Zeamanual Weldyes for being there and helpful in many ways. Finally my deepest thanks go to my family members especially my wife, Haymanot Eshetu who have been always beside me, helping me psychologically, emotionally, physically and materially to overcome all the obstacles I faced during my life. Thanks to them I arrive to this level and I will remain always grateful toward my family for what they have been doing. Finally to my office and all staff members those gave me the chance especially Honorable Mofrihat Kamil.

This work is dedicated to my parents for all the support and motivation they have given me throughout my life. I look forward to being able to give back to all of you. Thank you all!

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ACRONYMS

ANOVA	Analysis of variance
ASTM	American society for testing and martial
BBD	Box – Behnken design
ES	Ethiopian standard
FTIR	Fourier transform infrared spectroscopy
GHG	Green House gas
IB	Internal Bonding
ISO	International standards organization
LVL	Laminated Veneer lumber
M E	Modules of Elasticity
MC	Moisture Content
MO	Moisture Objection
MPa	Mega Pascal
Rr	Required resin
Sc	Solid resin content
Tm	Total material
TS	Thickness Swelling
UF	Urea formaldehyde
WA	Water Absorptions
Wh	Weight of hardener
Wp	Weight of particle

1. INTRODUCTION

1.1 Background of the study

Particle board is manufactured out of dry wood particles (chips) or fibers, which are coated with a synthetic resin binder and wax and formed into flat sheets under pressure (Gur jar, et.al., 2007). A permanent increase in the demand for wooden raw material is asking for an increase in the production of primary raw material. If no alternative way of providing the required raw material can be found challenges due to limitations in production area and climatic conditions. Forestry will try to increase the production of a single species on the available land and decrease the time of the rotation cycle to meet the increasing demand. But an increasing demand for one type of raw material leads to greater competition and higher prices for the raw material, as it is a limited source.

For the particleboard producing industry it might be necessary to concentrate on alternative raw material sources such as lignocellulose raw materials from monocotyledons (non-wood plants). The demand for wood and other biomass-based particleboard materials have considerably increased due to the rate of population growth in the world, Moreover, the world population currently consumes over 3.5 billion tons of green wood annually, which corresponds to about 0.7 tons per person. If the consumption rate of wood fiber and the rate of population growth stay constant, demands for wood fiber will increase by over 60 million tons each year (Kadja, et. al. 2011). Therefore, a huge imbalance between supply and demand will be inevitable. efficient conversion technologies and new products will play an important role in the wood fiber supply demand (Kadja, et. al. 2011). If the particleboard-producing industry succeeds in using lignocellulose raw material from non-wood plants as a direct substitute for wooden raw material it would have great advantages (Linnaeus University Dissertations., 2016). Lignocellulose material can be used as raw material for particleboard manufacturing. Besides wood, industries can use residues from agribusiness such as, cereal straw, bagasse of sugar cane, cornstalks, corn cobs, cotton stalks, rice husks, sunflower stalks and hulls. Cotton stalk and rice husk are the raw materials found in large amount at any level can decrease the final cost of the product (Milo, et.al, 2014). Cotton stalks was a waste by-product of cotton farming and a problem to dispose of as it tend to harbor parasites such as pink bollworm. The stalks are normally disposed of by burning, which contributes to the emission of harmful greenhouse gases which pollute the environment (Nkomo, et al., 2016).

Particle boards are mainly made from wood and other materials. The increase in demand for wood panel material in Ethiopia will result in exhaustion of the existing forest resources. The regeneration of forest takes considerable time and therefor it is unlikely that timber alone can serve as the raw material required by the wood product industries. Removal of forests also has a direct impact on the GHG concentration in the atmosphere. Use of agricultural residue and non- wood plants as a substitute for wood in particle board industry like cotton stalk residue will provide three bold benefits. The first one is partially reduce the increasing demand for wood there by saving forests. Second providing effective utilization of the cotton stalk, presently treated as waste and disposed of in the field by burning in open air and creating environmental problem, the third one it serves as alternative raw material for particle board production. From the above point, Cotton stalk is rich in cellulose and of comparable composition and fiber structure compering to many hard wood species (about 79% hollo cellulose and 24% lignin and less than 7% ash) (Shupe, at.al 2006) Up on the variety of the cotton the stalk has 1 to 1.75m long and the diameter just above the ground may vary from 1 to 2.5 cm. the property of the particles of the particle board are comparable to those made from wood particles (Shupe, et.al 2006).

Utilization of cotton stalk for particle board manufacturing will provide additional income to the farmers for supply of raw material to industry, and helping mitigation of the gas emission from burning it in open air indirectly by reducing the demand for frosts and has short term replacement with three months. The particle board produced from cotton stalk can be used for making furniture's, wall and roof paneling, in general for construction materials and other uses.

Ethiopia is rich in non-wood fiber materials. Residues of both agricultural and industrial process by products, naturally occurring uncultivated crops and on purpose or dedicated crops are found in different regions of the country with a significant amount. Therefore utilizing these materials for the purpose as a raw material for particle board production is recommended in many ways.

A number of studies on the utilization of the wastes of agricultural crops in the production of the wood- and plastic-based particleboard materials have been conducted, and the outcome of these studies showed that it will be beneficial to use the agro-fiber wastes in the production of particleboard material in terms of the environmental and socio-economic aspects. It has also the chances to produce wood based panels with the combination of wood chips. It is possible to produce particle boards from the wastes of agricultural crops like cotton, bamboo, palms, tea leaves and peanut shells having physical and mechanical properties required in related standards(Suleiman et al., 2013)(china et. Al. 2015)

Generally in Ethiopia cotton stalk is available estimated more than 8 million tons, without any benefit for industrial uses, except littlie amount cotton stalk for bio-mass in few localities. So investigating this raw material for different use may be help full for the future. Almost all categories of non-wood fiber are found in the country. According to this work particle board was produced from agricultural residues of cotton stalks and tested its quality like the mechanical and physical property of the products, weather it meet to the standard or not**.** And if this study works, there will other reason for the production and development of cotton in Ethiopia for different uses, in additions to animal food, textile, and edible oil and particle board production as well as for other uses like production of cellulose, adhesive, and other research studies.

1.2 Statement of the problem

Production of cotton in Ethiopia is increasing from time to time. According to the Investment Agency of the country, the potential of production and area of investment coverage for cotton is developing at different regions of the country. Specifically, there are areas of investments like areas of specialization for cotton in the regions, Benshangul Gumuz, Gambela, Amhara, Tigray, Oromia, Afar, SPNN and Ethiopia Somali. The main reasons or driving forces to increase the production of cotton is the demand for textile industry, animal food, edible oil processing and the population growth. On the other direction the increasing of population growth and development will be the driving force for the growth of construction materials in the country.

So demand for construction material is growing at alarming rate. In this case the need for fiber wood to produce particle board is one of the construction material that consumes forest wood which is ecologically burden for the next years. There are different particle board producing companies in Ethiopia, like Mayhew, Hawasa, Addis Ababa, and Dukem. These all company use forest wood mainly eucalyptus tree which is ecologically burden, and it has an effects on the cost of the raw material and will increase the product cost. Due to the difficulty of forest substitution with short period of time. The companies have trends of using wood particles, and no one is using for different raw materials in the current scenario. This all indicates competing for one type of raw materials that have an effect for the environments. The current global technology focus on different raw materials for the production of particle boards, and numerous research works are investigating in different parties of the world. Finding different raw material options are undergoing that by setting institutions especially for the lignocellulos Martials in many country like India, china and USA are counters using different agricultural residue as raw material for particle board production and applying in industrials pilot scales.

The other is establishment of research center for cotton stalk and other agricultural residues only by evaluating the economic and ecological aspects for small scale industry, and facilitating short and long term trainings for youths in higher educations and setting the industry with 50 km radius, to reduce the transportation cost and bulky density of the cotton stalk. Even if it is difficult to quantify the Cotton stalk currently it is available in Ethiopia, the production of cotton is increasing at a time and also decreasing for specified time do to the market intervention, and quality of productivity that have shortage of computation to the world market. But the residue is available in Ethiopia without any industrial application and computation. For future there will be briquetting for energy and pulp production that currently not in use. It has many application even it is not being in use. So, utilization as alternative raw material for the production of particle board is one issue that friendly with the environment, like cotton stalk which is fiber reach, may be promising raw material for the coming years, due to the following main reasons. Utilization of cotton stalk for particle board manufacturing will provide additional remuneration to the formers for supply of raw material to industry and helping mitigation of the gas emission from burning it in open air, as well as by reducing the demand for forests by using as alternative row materials.

1.3 Objectives

1.3.1 General objective

The general objective of this study is to produce particle board from cotton stalk with standard adhesive and study of its characteristics.

1.3.2 Specific Objectives

The specific objectives of this study are:

- To investigate the characteristics of cotton stalk morphology, proximate and chemical compositions;
- To produce particle board from cotton stalk using urea formaldehyde resin adhesives and to conduct physical and mechanical property analysis of the board;
- To investigate the effects of factors with pressing time, temperature and adhesive content on the quality of the board and optimizing the parameters for best production;

1.4 Significance of the Study

This study has main significance for the board industry and to the ecology as well as for the increment of cotton production. In general if this study works some of the significant will be;

- The raw material is renewable; out of seasons it can be cultivated by irrigation;
- Employment opportunities for rural youth establishment of cotton stalk supply chain;
- Additional income of the daily wage, like collecting, cleaning, supplying and other activities;
- Contributes significant cost reduction for particle board producers;

2. LITRETURE REVIEW

2.1 Definition of Particle Board

Particle board is manufactured out of dry wood particles (chips) or fibers, which are coated with a synthetic resin binder and wax and formed into flat sheets under pressure. Heat is applied with the pressure, to cure the resin binder. The resin binders used are urea formaldehyde (UF) for interior applications and phenol formaldehyde for exterior products. Bitumen is also used for certain specific end use. Particle board may have a uniform structure throughout its thickness or it could be a sandwiched matrix with coarser grains at the center and finer ones on both sides. It is manufactured in different thicknesses and forms, such as plain, single or both sides veneered, with plywood lamination (Shaikh et al., 2009)(Gur jar, et.al., 2007).in this study the particle board can be produced from cotton stalk with the standard adhesives other chemicals that can be used to see the property of the board.

2.2 Potential of Cotton Stalk in Ethiopia

State farm plantations, mostly concentrated in the Awash River Basin, dominate cotton production in Ethiopia. Some private cotton cultivators are also active in these areas and others. At present, the residues are not utilized but are burnt in the field to control pathogen and insect infestation of the following crops and are then ploughed under (Seboka, et. al. 2009). Cotton has grown in many of regions in the country. In each region there are wide potential areas according to the investment agency, Tigray 269130ha, in Amhara 678,710 ha, in SNNPR 600,900 ha, in Oromia 407420 ha, Gambla 316,450, Benshangul 303,170ha, Afar 200,000 ha and Ethiopia Somali 225,000ha. With the total area coverage 2,775,780ha. Most of the areas are low land and at river basins and the country has a Gross potential irrigable area 37,386,000ha and the irrigated area was 255,450ha. (Profile, 2012 Ethiopia Investimet Agency).The bulk density of cotton stalk residues collected in the field is approximately 140 kg/m^3. The bulk density of a material is defined as its mass per unit bulk volume. The bulk density of the cotton stalk was measured by measuring weight of known volume of sample (Aggarwal, et.al. 2006). The cotton-producing state farms in Awash are approximately 300 km from Addis Ababa (Sebeka, et. al. 2009). Economic transport and use of the cotton stalk residues would require that the material be densified. Cotton stalk and other residues from the farms can be densified directly, or charred and then densified, to make domestic and commercial, proven technologies are available. The total volume of residues from cotton plantations has estimated including the public farm area coverage under cotton was totally residue of cotton stalk in tones was over 1,549,136.5 per year in the country before 2007 with conversion factor 2.76 at 12% moisture contents (Seboka, et. al. 2009). Utilization of this raw material as alternative material to particle board is to be investigated further.

According to Seboka, the average production of cotton stalk is 3 ton per hector. The national distribution of the cotton residues production and distribution, according to Ethiopian investment agency, 2012 the productive area under cultivation is 2,775,780 ha and has residue of 8,327,346 tons of cotton stalk will be produced per year, all this is burn in open air that only small amount can serve for biomass energy in the local area of the country. So, using this as alternative raw material is promising to give relief even for specific period of time for forest woods. But including the locality produced by farmers the amount of stalk residue in Ethiopia according to the recent study shows the amount of cotton stalk production per annum is estimated that 208,milion tons in the country (Seboka, 2009). This indicates that the residue is increasing from time to time because of different driving forces and the interconnectedness of the society.

2.3 History of Agricultural Residue Particle Board

Particleboard is a wood-based panel produced under pressure and sometimes temperature using wood particles or other lingo cellulosic materials and an adhesive. It is commonly used in the production of furniture. The high rate of demand for forest wood consumption is considered as a main reason for the high rate of deforestation as well as serious impact on the environment which has resulted to global warming. Starting 1980s the growing demand for wood-based particleboards have raised serious challenges on the issue regarding the sustained supply of raw materials to this sectors for quite some time.

However, the need to reduce the dependence on wood and forest resources has resulted in a great interest for alternative resources substitute, wood raw material for agricultural residues and wastes for particleboard production. The alternative fibers such as agricultural residues and non-wood plant fibers could serve as the balance between supply and demand for the manufacturing of composite panels such as particleboard. The need to reduce the dependence on wood and forest resources has gained interest in the utilization of agricultural residues and wastes for particleboard production. Many researchers have conducted studies on a wide variety of agricultural wastes and residues from many different regions of the world. It enhances total wastes utilization, reduces cost of production, promotes a cleaner environment and enhances the earning of the farmers. It also prevents burning of agricultural residues and wastes and thus mitigates climate change.

Different value added products has been produced from agricultural residues (Davies & Davies, 2017).

2.4 Uses of Particle Board

Common Uses of Particleboards are domestic and industrial users the consistent quality and design flexibility to improve the quality of consumer products. Particleboard panels are produced in different dimensions. particleboards have been found to useful in office and residential furniture, soundproof, home decking, ceiling, roofing, shuttering, cabinets, partitioning, prefabricated houses, cladding stair treads, underlying floor, table, shelving, store fixtures, counter and desktops, office dividers, wall bracing, boarding, sliding doors, kitchen worktops, interior signs, exam pad, photo lamination, low cost cabins peaked box, bulletin boards, packing boxes, thermal insulation and other industrial products.

The particle boards from cotton stalks possess all the desirable properties sought for internal as well as external applications. However, it may be mentioned that boards made from cotton stalks using urea formaldehyde as binder lack in water resistance properties as compared to boards made from other raw materials, which is mainly, due to higher percentage of bark having more fibers resulting in increased absorption of water. These boards can also be made fire resistant, termite resistant, etc. by use of chemical additives (*M.R Gurjara et.al., 2007*). This problem is not observed in phenol-bonded boards. However, by use of different chemical additives, like bio-phenol formaldehyde the water resistance property can be improved with minimal increase in the cost, in this work that can be evaluated later, due to the property of oil and water.

2.5 Cotton Stalks Cleaning and Transportation System

It has been found out that the presence of boll rinds and adhering lint affects the quality of boards. This necessitates the removal of them before chipping. Manually this is done by beating the uprooted or cut stalks gently against a wooden mallet. This is labor intensive. Wherever labor is a problem, machine removal becomes necessary. A cleaning system important in order to reduce the labor. The following unit operations are mandatory during cleaning. Scratching system (peeler), Conveyor system, Air blowing chamber and Air suction chamber are mandatory. And will help in the removal of 90% of the boll coats. This will help that the scratching system could be directly connected to a chipper to economies the process (*Patil,et.al,2007*) In order to achieve this work the need for logistic is the other said, that one can be understand to be most suitable and economical way of collection of cotton stalks and its processing. Transportation of cotton stalks directly from the field to factory for chipping in the factory one way, Chipping using labour and transportation to the factory the other way, and Collection and transportation by labour from the field to chipping centre, chipping and subsequent transportation to the factory. The other alternative is using economical machinery like tractor driven mobile chaff cutters are ideal and economical because they can be taken very easily from field to field, they could be run on single phase power supply which is easily available in rural places (*Patil, et.al*, *2007*). In Meany literatures there is a recommendations that the factors can set near to the raw material availability in 50 km radiuses.

2.6 Technology of Particle Board Manufacturing

Particle Board is a panel product produced by compressing small particles of wood while simultaneously bonding them with an adhesive. The various types of particle boards differ greatly with regard to the size and geometry of the particle, the amount of resin (adhesive) used and the density to which the panel is pressed. The properties and potential uses of board differ with these variables. Particle board has emerged as a versatile substitute for wood in many applications such as paneling, partitioning, false ceiling, furniture making, etc. Detailed studies have been made since to arrive at the appropriate process sequence and to identify process parameters that would ensure the required qualities for the particle board (*Bela kang, 2007*). By using different chemicals and additives, the boards can be made water proof, fire proof, treatment resistant, etc. These boards have been found to meet BIS specifications in respect of quality characteristic (*Belakang, 2007*). Due to the lower cost of raw material and reduced power required for its conversion into finished product, the cost of particle board made from cotton stalk will be much lower than that of boards made from wood.

2.7 Blend Adhesive (resin)

Wood–Organic Adhesive Composites the synthetic organic adhesives commonly used in the production of particleboard wood based materials are phenols and formaldehydes. However, formaldehyde is declared to be carcinogenic. Based on health concerns, legal restrictions exist for the usage of formaldehyde. Phenol or urea formaldehyde resins are of significant importance for the panel board industry. Phenol formaldehyde possesses both a high dry and a high wet bonding strength, and a strong adhesion to wood. Urea-formaldehyde resins (UF) have the widest application range of all synthetic resins based on their high adaptability. They are also utilized for the production of weather-proofed fiberboards and particleboards, plywood, isolation boards, and for the generation of wafer and oriented strand boards (H.Network 2008).

Alternative binders based on renewable resource materials, such as soy, do not release formaldehyde during use and manufacturing the board. This can be applied mix with epochlorohydrin, future will use in combination with the soy powder. (Qiao, et.al., 2016.). But the epochlorohydrin highly reactive and volatile even if it is used to produce epoxy resin which is difficult to fire safety. Process-ability manufacturing of wood composite like medium density board, particle board, plywood based on UF resin is a difficult task for manufactures because various factors that can interfere with the curing process. Urea Formaldehyde resin is depend on the following factors

1) Wood extractive
2) Wood pH values (Fiber acidity)
3) Wood particle size/fiber dimensions
4) Formaldehyde: Urea ratio
5) % Solid content of UF resin
6) Type of catalysts & Amount of catalysts
7) other polymer addition

This factor should be considered during manufacturing of wood composite. (Gadhave, et.ai,. 2017)

2.8 Particle Board Production Method

Determination of processing conditions (temperature, pressure, time and resin content) and synchronization of different parts of the system. Effect of different processing conditions on quality parameters of cotton stalk particle boards, Identification of different processing conditions for different end-uses (paneling, table tops, false ceiling, partitioning etc.), Production and evaluation of boards with different surface finishes Production and evaluation of boards with different binder's adhesives, Effect of different chemical additives, and on process conditions and board qualities are the main methods. So during the production of the cotton stalk production the main parameters the pressure, temperature, pressing time and chemical dose concentrations are the methods that need attentions in this work.

2.9 Production Process of Cotton stalk Particle Board

Particle Boards can be manufactured in desired shapes and sizes with suitable binders or fibers impregnating with resins such as Polyester, Urea Formaldehyde, Melamine Formaldehyde, Phenol Formaldehyde, Epoxy resins etc. The important equipment required for the production process were dryer, shredder, material handling equipment, grinder, sieve shaker, resin impregnation unit, hydraulic presser with heating arrangement (Muruganandam, et.al, 2016) The process of particle board preparation involves chipping of stalks, grinding of particles to suitable mesh size in a pulverize, mixing with suitable binder and catalyst, adjusting the moisture content, mat formation and pressing between the heated platens of a hydraulic press to form the board. By using different chemicals and additives, along with binder these boards can be made water proof, fire proof, termite resistant, etc. According to (Bela Kane, 2007) the process particle board production involves the following steps

- ❖ Chipping of stalks to 1.5 - 2.0 cm size;
- ❖ R-chipping to particles of 20 mesh size and 8 mesh size;
- ❖ Mixing of chips with synthetic binder different resin;
- ❖ Preparation of a three-layered mat using coarse and fine;
- ❖ Pressing the mat between heated platens of a hydraulic press for specific time and pressure.
- ❖ The board thus made is cooled to attain dimensional stability
- ❖ Cut to the desired size.

2.10 Factors Affecting Properties of Particleboards

There are many factors affecting the characteristics of the particleboards and the most prominent among them are species of wood, fiber structure, density, hardness, compressibility, type and size of particles and technique of particle drying. Other factors include particle screening and separation, particle size distribution, type and amount of binding agents, method of mat formation, structure of particleboard, moistening of particles prior to pressing, final moisture content of board, conditioning, curing conditions, thickness of board. Based on the findings of different researchers.

2.11 Physical and Mechanical Properties of Particleboards

A. Physical Property of the board

During characterization of the board produced from cotton stalk it can be evaluated its physical properties compering to the standards. Some physical properties can be determined in accordance with appropriate standards like moisture content (MC), density, water absorption (WA), thickness swelling (TS), for 2 hour and 24 hour immersion. This investigation is important for checking that the cotton stalk will substitute the raw material for the wood based forests used as input for particle board.

B. Mechanical Property

The other investigation of the products is the mechanical properties such as modules of elasticity (ME), internal bond strength (IB), dry modulus of rupture or screw holding strength (SH) are the main properties that can be analyzed (L et al., 2011). During the particle board productions all to measures of the mechanical properties can be analyzed according to standards of the particle boards. In general the physical and mechanical properties of the boards are very important for the recommendations of the study in order to differentiate the application of the material and to conclude weather the stalk serve as alternative material or not.

2.12 Design of experiments

The terminology of experimental design is not uniform across disciplines or even, in some instances, across textbooks within a discipline. For this reason, a discussion of statistical experimental design with a brief definition of terms can be important. Those are Factor, response, level factor, randomization, replication, and block (Wong, 2012) are important in this study.

Factor: controllable experimental variable that is thought to influence the response, e.g. temperature, pressure, moisture content, etc. Each factor is either a treatment factor or a blocking factor, and it is either fixed or random. Response: Outcome or result of an experiment performed.

Level of factor: Each factor is usually set at several levels, i.e. it is given several values. If the set of levels is numerical, the corresponding factor is referred to as being quantitative. The different combinations of factor levels provide the different conditions to which the experimental units are subjected. The response of the units to these varying conditions is subsequently analyzed.

Randomization: Normally, the order in which the experimental units are allocated to the different combinations of factor levels should be done in a completely random fashion. This is usually achieved by using a table of random numbers, or by tossing a die, or shuffling cards. The main aims of randomization are to reduce bias in the conduct of experiments and to ensure that measurement errors are independent**.** Replication: Repetition of an entire experiment or a portion of an experiment under two or more sets of conditions. An average test result will be obtained for analysis in order to monitor and minimize any human error.

Block: A group of experimental runs conducted under relatively homogeneous conditions. Although every measurement should be taken under consistent experimental conditions (other than those that are being varied as part of the experiment), this is not always possible. Blocks are used in experimental design and analysis to minimize bias and error variance due to nuisance factors.

3. MATERIALS AND METHODS

3.1. Materials and Chemicals

The materials used were Cotton stalk, urea formaldehyde (UF) bought from Addis Ababa Markato "Mikey wood center". Ammonium chloride ($NHCl_4$), paraffin wax, Aluminum foil, distilled water, Nitric acid, Sulfuric acid, benzene, and ethanol was bought from Neway chemical and laboratory equipment shops in Addis Ababa and chromic acid was found from Ethiopian Forest and Environment Research Institute laboratory.

3.2 Material Collection and Preparations

The raw material cotton stalk was collected from Afar region, awash zone, Werrer Agricultural Research Center 340 km far from Addis Ababa. After collection of the stalk cleaned and chopped using knife to the appropriate size of 5 cm to 9 cm as shown in Figure 3.1 to dry to the required moisture content of 12-15% (Chen et al., 2007). This was done in order to densify the material or to reduce the bulk density and moisture contents for easy transportation. Finlay packed in sack and transported.

Figure 3.1 Chopped cotton stalk on drying

3.3 Equipment used

During this study equipment were used mainly for the productions of the board, Size reduction equipment (axe or knife cutter, mill), electronic balance, pH meter, thermometer, heating mantle, plastic bags, beaker, spoon, tong, cylinder, molder, hydraulic press, different size Sieves, calibrated Microscope with ruler accessory, Material strength testing equipment (universal testing machine), water bath, pH meter, viscometer, round bottom flask, water base, Small flasks, small mixer, Oven , furnaces, crucible , water bath, vacuum filter, attrition mill, round bottom flask, caliper, metal plate, slice cuter, microbial tube, slide, shaker, rotary evaporator, band sow cuter, computer, cuter, safety wear, universal testing machine and others equipment like deferent kinds of soft wares was used, in laboratory during the morphology, characterization of the stalk, production of the boards and testing the quality of the board.

3.4 Raw Material Preparation for Characteristics and Board Production

A. Drying the Cotton Stalk

After collection and chopping the cotton stalk at Werrer Agricultural Research Center with the size of 5cm, it was sun dried properly for 10 convective days in the laboratory, and prepared for farther size reduction Photos of sun dry raw material preparation was indicted on Figure.3.1 at Ethiopia Forest and Environment Research Center Institutes, size reduction laboratory.

B. Grinding and Sieving

Small sample cotton stalk was crashed before starting any determinations and the material preparation. The raw material was prepared using the grinding mill to different size, first the sun dried cotton stalk was grinded by using the model (Stanmore, middex HA 7 1BU Eour) to the measured size of range from (9-2.75) mm three times separately. Then sieved using sieve size of 9 mm, 4.75 mm, 2.75 mm and 1 mm, the size less than 2.5 mm which retain at 1mm sieve size was grind further to the size of 250 micro meter using the model (Retch SR 200 ALTY scientific) grander, at the laboratory of Ethiopian Forest and Environment Research Center Institute size reduction laboratory. Sieved using the sieve size of 250 μm size. Finally the 200 gram sample with 250 μm size was prepared and packed in plastic bag, used for the determination of chemical compositions, proximate determination and FT-IR. Because sample was prepare carefully for homogeneity of the grind sample and to obtain good laboratory result.

The other work was grinding the stalk for the particle board production using the same crusher for additional moisture removal and to separation of the bark about 95 %. Separation of the bark was done deliberately, to reduce the resin consumption and to increase pressing ability to reduce spring back during pressing, and high water up take as shown on Figure .3.2. After separation of the bark the size reduced to less than 9 mm and sieved using the sieve size of 9 mm, 6 mm, 4.75 mm, 3.5 mm, 2.75 mm, and 1 mm orderly, and stored in separate plastic storages according to the size of the particle. Finally, it was grinded for additional size reduction at School of Chemical and Bio Engineering laboratory Addis Ababa Institute of Technology size reduction laboratory to final size of board production with a machine (Retsch GmbH 5657 HAAn Germany) using size of 6 mm, 4 mm, 2 mm sieve size and sieved using sieve size arrangements from (4, 3.5, 2.5, 2, 1.8, 1.4, 1) mm sieve with decreasing order size using sieve machine shaker (Retsch GmbH Rheinische star Be 36). At the end, the sample was prepared to the desired size using the above sieve size and stored separately at plastic bags with the size of 1 mm up to 1.8 mm was fine and the size 2 mm up to 3.5 mm was coarse particle.

Figure 3-2 Experimental set up of size reduction process

After the size reduction process was completed the raw material was oven dried for farther removal of moisture contents to the desired production of the particle board, which was mostly advisable for lignocellulose material (2-5) % moisture contents using oven dry (Umesh, et.al., 2015). Moisture content (MC) of cotton stalk was drying with known weight of sample in hot air oven at 105 ^{o}C for 24 hours while keeping the milled sample in dish till it become constant weight less than 5% as shown on figure 3.3.

Figure 3-3 Oven dry of final crushed cotton stalk

This was important in the selection of wood based raw materials for industrial purposes especially to determine the product moisture regain. The experiment was done at Ethiopia Forest and Environment Research Centre Institute laboratory. Finally the coarse (2-3.5)mm and fine (1-1.8)mm raw material was stored in different plastic bag bought form Neway chemical shop paisa Addis Ababa to remain with constant moisture contents.

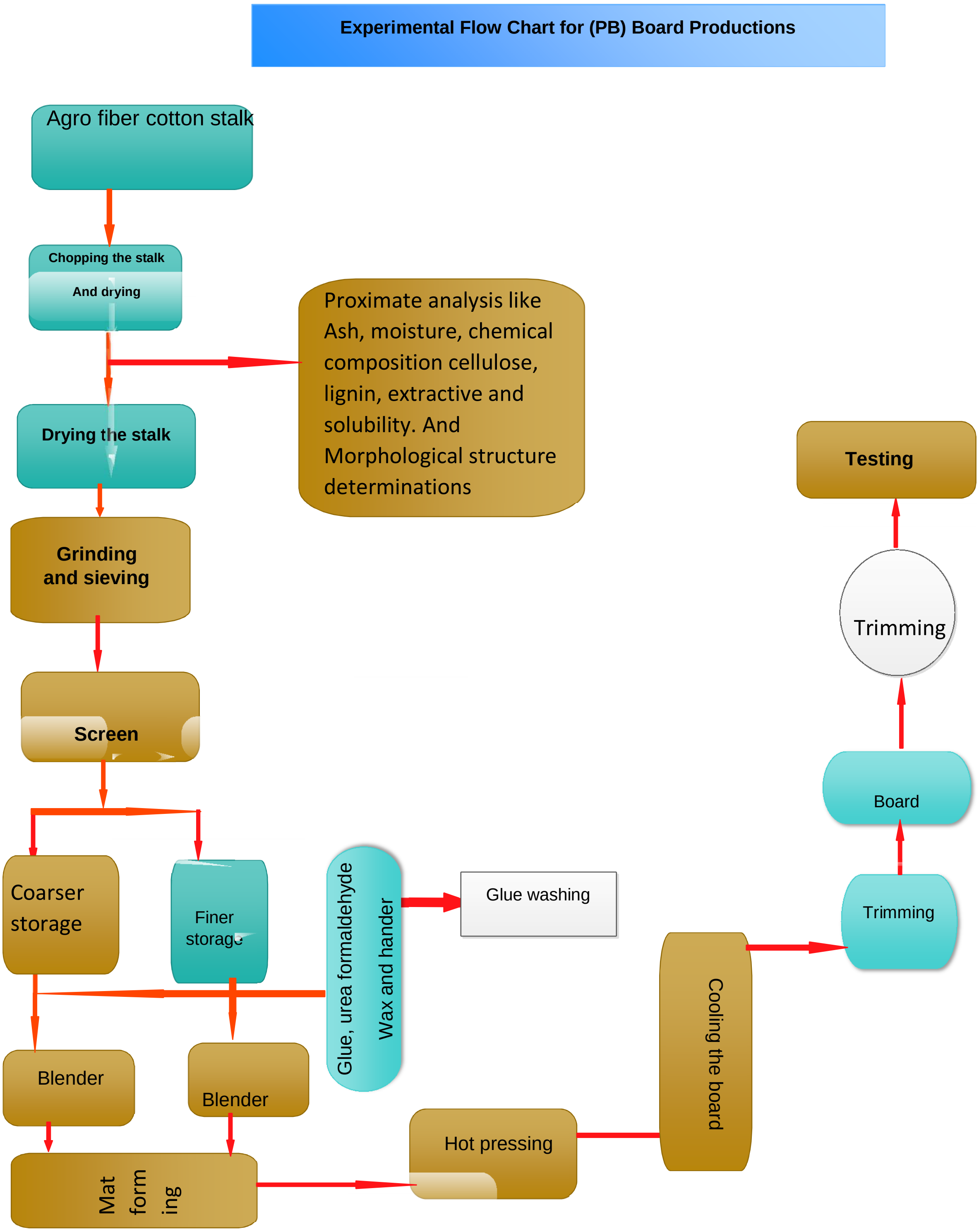

Figure 3-4 Experimental flow chart of particle board production

3.5 Analysis of Cotton Stalk Morphology and Chemical Compositions

During this research work the anatomical structure and the chemical composition of the cotton stalk was determined, mainly, those related to the study of the main objectives. Starting from the morphological structure determination like cell well thickness, lumen diameter, fiber length and thickness (width) was selected. On the other hand, compositional analysis like cellulose, lignin, hemicellulose and alcohol toluene extractive, hot and cold water solubility of the stalk was selected and investigated, from the proximity analysis the ash and moisture content was determined. Because, those parameters are important for the comparison of the board final use, as well as to test the product comparing to those hard wood products. So the above parameters were determined carefully in laboratory. All experiment was conducted at Ethiopia Forest and Environment Research Institutes Research Center.

3.5.1 Morphological Structure Determination of Cotton Stalk.

Morphological structure of Cotton stalks are branched and carry leaves and an opened cotton bolls. They still retain the roots. The stalks consist of the bark and woody core. The bark constitutes about 25 % and the woody core about 75 % by weight of the whole stalk (Fahmy, et.al, 2017). Comprising the fiber length, width, lumen and cell well thickness were determined starting from the fiber analysis, and referring to other works and to the wooden materials mainly used for the particle board productions.

A. The Fiber Length and Thickness Determination

The fiber analysis was done by taking greater than match stick size sample of the cotton prepared from the stalk with the length of 2 cm and width of 0.5 cm cut with equal size and the safari solution was prepared from 69% ($HNO3$) taking 15 ml of nitric acid and 15 ml chromic acid was gotten from (Ethiopian Environment and Forest Research Institute anatomy laboratory) add to 190 ml distilled water and mixed well. The safari solution was add to small microbial tube, and the specimen or sample was immersed in the papered solution for 10 days. After that the sample was dissolved and separated to fibers which is thinly fiber was seen and washed with distilled water, then the dispersed fiber was put on microscopic sild and observed using the Mo-tic magnifying electron microscope. And using the Mo-tic image pulse 2 soft war, data was recorded on Table A-1 Appendix A. The laboratory set up and the microscopic picture of fiber length and its thickness was observed the on Figure 3.5.

Figure 3-5 Experimental set up for lumen cell well and fiber determination

B. The Cell Well Thickness and Lumen Diameter Determination

To determine the lumen diameter and cell well thickness a sample was taken from the prepared cotton stalk with height of 2 cm with 1 cm thick as shown in Figure 3.5, preparing with rectangular shape and immersing in becare of 50 ml of distilled water for 24 hours, and became soften for cut using the sliding microtone machine of (Altany scientist S.P.A 00046 grottafe rrta, lome (Italy) slice cuter microtone (LEICA RM 2255), then putting the cut or slice to slide of the microscope by using alcohol reagents these are 30%, 50% ,75% alcohols and 97% xylene chemical found form (Forest and Environment Research Institute botany laboratory). After immersing the slice cut of the stalk in the different concentration alcohol in each of at list for 30 seconds. Finally it has a flat shape and then washed with the xylem chemical to avoid the alcohols used for dehydration or drying carefully on the table for observation using the Mo-tic microscope as showed in figure 3.5. The result was recorded using the Mo-tic image pulse 2 software and measured about 60 fiber and 60 cells were determined. The data of lumen diameter and cell well thickness were recorded in Table A-1 Appendix A.

3.5.2 Proximate Analysis of Cotton Stalk

A. Moisture Content Determination

Determination of moisture content is important during any production of materials, especially using wood products. To determine the moisture content 10 g of sample with the size of 250 μm Grained stalk was taken and conditioned at room temperature in a desiccators for 48 hours and 2 g of sample was weighed from, and added in a properly oven dried and weighed crucible in hot air oven (yco-no1) dried for 2 hours at 105^{o}C and cooled in a desiccator for 30 minutes after properly cooled, the weight was measured by using the digital balance scale and result was recorded. This step was done seven times convectively with 3 crucible once and the results were listed in the data sheet on Table C-1 Appendix C and determined using the formula calculation.

$$M.C\ \% = \frac{\text{weight of air dry (wa)} - \text{weigth of oven dray(wo)}}{\text{weight of air dry (wa)}} * \qquad (3.1)$$

B. Ash content determination cotton stalk

The ash content was determined according to *(ASTM D 1102-84)* 250 micrometer size grained cotton stalk 2 gm sample was taken and put the specimen in the crucible after burring the empty crucible in the muffle Furnace at the temperature of 650 for 30 minutes and weighted and recording it. The sample was put in crucible and inserted to furnace at the temperature of 650^{o}c for 2 hours and cooled in a desiccator for 15 minutes and weighted and recoded in experimental data was showed on Table C-2 Appendix C this process was done three times after the performing the result was determined using the formula for ash content determinations.

$$A.C\ \% = \frac{\text{Weight after burign (W2)}}{\text{Weight befor buring (W1)}} *100 \qquad (3.2)$$

3.5.3 Determination of Chemical Composition of Cotton Stalk

A. Determination of Cellulose Contents

The cellulose of the stalk was determined (by Kushner and Hoffer method) using reagents of 95% ethanol and 69% concentrated HNO_3. The 98% ethanol was diluted to 95% ethanol with distilled water of volume using the formula

$$C1V1 \ = \ C2V2, \qquad (3.3)$$

Where c stands for concentration and v is volume in ml.

For this experiment 20 ml of 95 % ethanol was mixed with 80 ml of 69% HNO_3 which means 100 ml solution for one sample, for triplicate sample 900 ml was prepared and put in 2000 ml of bottom round flax and cooled. By weighting 3g of grained cotton stalk sized 250 micrometer put in three bottom rounded flask 1g in each and 100 ml solution of the prepared regent was added to one g sample. Steed on the water bath at 110 ^{o}c, for 90 minutes with chilling process. The well oven dried empty filter crucible weighed and recorded, the sample was filtered using vacuum filter by reflexing (extracting) three times. Finally inserted in hot air oven (yco-no1) at 105^{o}c for 2 hours and cooled in desiccator. Result was calculated as shown in Table B-1 Appendix B, using equation (3.4)

$$\boldsymbol{Cellulose}\ (\%) = \frac{wf}{ws} * 100 \qquad (3.4)$$

Where, *wf* cellulose weight after filtration in gram

Ws, weight of sample in gram

Figure 3-6 Experimental set up of lignin and cellulose determination

B. Determination of Lignin Contents

Lignin is an aromatic amorphous substance containing phenolic methoxyl and other constituent groups its chemical structure is not fully evaluated. Lignin is defined as wood constituent insoluble in 72% of sulfuric acid. The determination of lignin, was done according to *ASTM 1106 – 56 (1977)* sulfuric acid, ethanol, benzene and distilled water was the main laboratory solutions solvents used. The solution was prepared in the ratios of 1:2 by volume of ethanol and benzene respectively. In this study 98 % ethanol was diluted to 95 % ethanol with distilled water of volume using the equations of

$$C1V1 = C2V2 \quad (3.5)$$

Where C= stands for concentration and V= is volume in ml**.**

By using 484.5 ml of 98 % ethanol and 15.5 ml of distilled water then 500 ml 95% ethanol was prepared. After this, mixture of 300 ml benzene and 150 ml 95% ethanol was prepared using 1000 ml round bottom flask and added to the soxhilet. On the other hand, 5 gram of 250 micrometer grounded cotton stalk was weighted and put in the thimble inside the soxhilet extracted for 4 hours at temperatures of 110 ^{o}c. After this process the extractive free sample was adjusted in heating mantel for 3 hours and filtered using the filter prepare and air dried for 48 hours. 3g of air dried sample was weighted and put in cylindrical becare of 15 ml, 72 % H_2SO_4 was added to each becare and mix with the sample and steer frequently to be mix well for 2 hours. Finally it was added to bottom round flask by aiding 560 ml distilled water to dilute the H_2SO_4 to 3% then reflexed for 4 hours using the water bass at 110 ^{o}c. and cooled followed by adding sample to vacuum crucible. Finally put in hot air oven at the 105^{o}c for 2 hours and result was calculated in a data sheet calculated using the formula of lignin determination.

$$\text{Lignin (\%)} = \frac{wl}{ws} * 100 \quad (3.6)$$

Where, *wl* is weight of lignin in g and *ws* weight of air dry sample in gram

C. Determination of Hemicellulose

Hemicellulos determination was cared on according to *ASTM test methods of 1107-96 (2007)* done by direct extraction with aqueous alkali by taking sample of 200 g of milled cotton stalk with size of 250 micrometer and extract directly with 5 %, of 2.5 liters of aqueous sodium hydroxide (NaOH) prepared with distilled water without prior lignification. The extract was filtered and acidified with acetic acid. Then the hemicellulose fraction was precipitated by addition of 1.25 liters of ethanol collecting the precipitate by centrifuge and washed successively with 50% ethanol anhydrous and ethyl ether finally, the product was dried over phosphorus pentoxide under vacuum and gotten a soft brownish powder. The result on (Table B-3 Appendix B) was calculated using equation (3.7)

$$Hemicellulose\ (\%) = (w2/w1) * 100 \quad (3.7)$$

Where w_1 is the amount of dry sample for analysis and w_2 is the dried residue after analysis

D. Hot Water Solubility

The hot water solubility of cotton stalk was determined according to *ASTM 1110-56.* 2g of 250 micrometer milled cotton stalk sample was measured and added to 250 ml of round bottom flask containing 100 ml of distilled water. The sample was reflexed for 3 hour using water bath set at 110^{o}c. Then the sample was placed in filter crucible to remove the water using vacuum filter, and oven dried at 105 ^{o}c, for 2 hours. The dried sample was continuously weighted till constant weight was recorded. The result (Table B-4 Appendix B) was calculated using equation (3.8).

$$Hw\ (\%) = \frac{w1-w2}{w1}*100 \quad (3.8)$$

H w = hot water % extractive

W1 = weight of oven dry sample (g)

W2 = weight of oven dry after extractive with hot water

E. Cold Water Solubility

The cold water solubility of cotton stalk was determined according to test method *ASTM 1110-56.* 2 gram of 250 micrometer milled cotton stalk sample, adding on 500 ml round bottom flask with 300 ml distilled water on it, and stirred for 48 hours using magnetic stirrer instead of using manually stir. Finally the well mixed residue was poured to filter crucible. And oven dried at 105 ^{o}c, for 2 hours and measured till the constant weight was recorded. The result on (Table B-4 Appendix B) was calculated with equation (3.9)

$$Cw\ (\%) = \frac{w1-w2}{w1}*100 \quad (3.9)$$

Cw = cold water % extracted

W1 = weight of oven dry sample (g)

W2 = weight of oven dry after extractive with cold water

F. Alcohol benzene extractive

The Alcohol benzene extractive of cotton stalk was determined according to test method *ASTM D1107-56 (1972)*. 2 gram of 250 micrometer milled cotton stalk sample, was added to cellulose extractive thimble and put in soxhilet, and attached to round bottom flask which was well dried and measured its weight. Then alcohol benzene solution was prepared with ratio of 2:1 with 300 ml 95% of ethanol to 150 ml benzene solutions and 150 ml of the solution was added to the soxhilet and extracted for 8 hours till the solvent become color less. Finally the solvent was evaporated using rotary vacuum evaporator till the solvent was removed. Extractive was remained in the round bottom flask and dried in oven at 105 ^{o}c, for 2 hours, then measured till it become constant weight and the final result on (Table B-5 Appendix B) was calculated using equation (3.10)

$$A\ T\ (\%) = \frac{w2}{w1} * 100 \quad (3.10)$$

AT = alcohol toluene

W1 = weight of oven dry test sample (g)

W2 = weight of oven dry extracted residue (g)

3.6 Fourier Transform Infrared Spectroscopy

The infrared spectrum was recorded by passing a beam of infrared light through the sample. The functional group analysis of the cotton stalk was carried using FTIR spectroscopy. The FT-IR spectra were recorded on spectrum 65 FT-IR (PerkinElmer) and scanning a wave length range from 400 -4000cm-1 solid potassium bromide (KBr) beam splitter and solid pellets made of suspension. Using 0.25 mg of the cotton stalk and 0.5 mg of the solid potassium bromide (KBr) were prepared and examined. Diffuse reflectance system (DRS) was used for powder samples of cotton stalk and potassium bromide (KBr) was used as transmitter. Sample was mild further and put on plate taking both and pressed with 10.5 pascal for 4 minutes.

3.7 Mould Preparation for Board Production

For the casting operation mould is important. In this work Flat metals was used for the construction of moulds (Suleiman et al., 2013). The laboratory scale of metal sheet was designed for mat formation, used for casting. In this case it was specified maximum measurements of 21 cm by 21 cm and height 1.5 cm (Omar, et.al., 2017). The metal sheet have thickness of 0.8 cm in order to resist the hydraulic press with required pressing pressure. The mould has two holdings with the some thickness and 2.5 cm width. The mould has four holes at the back, used for removing of the board, and 20 cm by 20 cm supporting flat metal sheet with same thickness in said it to protect the board from the holes. Additionally the mould has a cover with the same thickens and area of 20 cm by 20 cm with tong holdings, which was used for handling during productions of the boards.

3.8 Experimental design for particle board production process

In this study the particle board was produced using cotton stalk, urea formaldehyde as resin adhesive and hardener. Experimental data analysis was done using design expert version 7.0.0 software. The experimental design selected for this study was the response surface methodology (RSM) three level-three factor Box-Behnken Design (BBD) and the response variable measured was mechanical properties of the board.

The three independent variables studied for the production of the board were heating temperature, (150, 165, and 180) ^{o}c, chemical adhesive (8, 10 and 14) % and pressing time (10, 15, 20) minutes. As indicated on the literature factors are numerous, but in this study the main factors were selected. Their interaction effect was analyzed to determine the quality of the board, and to obtain the optimum result at which the result approaches to the standard at normal condition and for general propose use. The three-level- three factor BBD was used in the optimization study which was conducted 17 experiments. The data was statistically analyzed using Design expert software 7.0.0 to obtain suitable model equation for maximum quality of the board and mainly better internal bonding and bending strength of the board. Table 3.1shows the lists of the range and levels of the independent variables studied. The lower and the higher levels were chosen by considering the operating limits for medium density particle board process productions.

Table 3-1 Independent variable and levels used in BHD for particle board production

		Levels		
Variables	**units**	**-1**	**0**	**+ 1**
Chemical dose	% (percentage)	9	11	14
pressing temperature	°c (Degree cilices)	150	165	180
Pressing time	minutes	10	15	20

In Table 3.2 the complete experimental design matrix of BBD for the factorial design was indicated. The order in which the runs were made randomized to minimize the systemic errors.

Table 3-2 Complete experimental design matrix.

Run	**Actual factors**			**Selected responses**	
	Chemical dose	**Pressing time**	**Temperature**	**Modules of rupture (MOR)in MPa**	**Internal bonding (IB) in MPa**
3	8	20	165		
10	11	20	150		
11	11	10	180		
4	14	20	165		
2	14	10	165		
14	11	15	165		
1	8	10	165		
9	11	10	150		
8	14	15	180		
5	8	15	150		
16	11	15	165		
15	11	15	165		
12	11	20	180		
13	11	15	165		
7	8	15	180		
6	14	15	150		
17	11	15	165		

3.9 Experimental setup

During production the feed material (the cotton chips, the resin, hardener, wax and distilled water) were done on the mixer. Mix with hand and the mold covered with aluminum foil adjusting the fine mat at the bottom, and top layer the coarser at the center, which was mixed with the resin individually to form the mat. Then the heater is adjusted to the desired temperature adjusting with thermometer and the cover was heated alone to protect heat loses from the board to the coverer. Finally, at the desired temperature the cover was covered to the mould and put on the mechanical hydraulic press with the desired temperature, pressing pressure and time. The board was cooling at room temperature then trimming with small cuter saw bandage in the mechanical laboratory.

3.10 Feed material requirement

During the production time, the material required per board was dependent on the chemical adhesives, amount of fine and coarse particle proportion and hardeners, in addition to the target density. In this study the target density of the board was taken 0.75 g/cm^3 as reference, for all medium density particle board, it was assumed that the target density can be in between of (0.4-0.8)g/cm^3 (Muruganandam et al., 2016) and thickness of 1cm. This is the most commercially available in all markets unless it was ordered by the costumers for special purpose. In addition to this the total area of the mould was 21 cm by 21 cm and height of 1.5 cm. So using this as reference the material feed can be calculated as follows

The total material required per board with the target density of 0.75 g/cm^3, area of the mould and thickness of the board was calculated with the following empirical formula

$$V = l * w * t \quad \ldots 3.11$$

Were v, volume of the mould, l, length of the mould w was width and t, stands for thickness of the board. The total material per board can be calculated

$$T.m = v * \text{p} - \%\ \text{oven dry MC} \quad \ldots 3.11.1$$

Were T. m, is total material required in gram and p, is target density in g/cm^3.The total material means the sum of required resin in gram, total chips and hardener.

$$T.m = Rs + Wp + Wh \quad \ldots 3.11.3$$

Where, Rs, is weight of resin required in gram (UF), W p, weight of the particle the (coarse and the fine) chips in gram and Wh is weight of the hardener in gram.

In this study for three layered particle board the proportion of the particle ratio was considered as 6: 4 ratio based on previous research (Wong, 2012), top and bottom layers of particleboard contribute 40 % of the total weight, The core layer contains 60 % of the total weight of the particles . Therefore, the weight of core and surface layers can be simply calculated as:

$$Wcore = 60\% \, x \, Wp \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \; 3.11.4$$

$$Wfine = 40\% \, x \, Wp \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .\,.3.11.5$$

So from the above point the total weight of the residue can be the sum of the fine and coarser material cotton stalk.

$$W\text{p} = Wcoares + Wfinn \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .11.6$$

The solid resin content can be calculated according to the required percentage of chemical dose and solid content of the resin as given by the supplier. The resin is urea formaldehyde (UF) which was supplied by Mikey chemical, It was made of Egypt Cairo with the solid contents of 60 % and the hardener was $NHCl_4$ with the sold contents of 95 % bought from Neway chemical shop Addis Ababa paisa, which is made up of India and this shows that 40% and 5 % of the resin and the hardener was water. From this point of view the chemical dose for this study was selected that 8%, 11%, and 14% respectively. So, this was important to calculate the required resin and liquid resin equivalents.

The amount of resin required (Rr) can be calculated dividing the given percentage chemical dose (Pd) per board, by the present of sold contents of the resin (Sc) given by the supplier and multiplied with total materials of the board with the following empirical formula.

$$Rr = \left(\frac{Pd}{Sc}\right) * Tm \;\; per \; bord \; at + Mc\% \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .3.11.7$$

Mc is Moisture content of the resin. Where, (Tm) was total material required per board. Once calculated the total material (Tm) and the required resin (Rr). Others could be calculated easily, the weight of the total chips (Wp) and weight of hardener (Wh) in gram. The weight of required hardener was calculated with the formula

$$Wh = \left(\% \frac{dose}{sc}\right) * Tm \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .\,.3.11.8$$

Where, in this study (%) of the required hardener was 2% and the solid weight of the hardener given by the supplier was 95%

From equations 3.11.3 the weight of the oven dry particle or chips (Wp) can be calculated that with formula

$$(Wp) = Tm - (Rr + Wh) \;\; \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.11.9$$

Finally the amount of water required was calculated using the water contents of the resin as the supplier. In this case the water contents of the resin was 40% then water required can be calculated using the formula

$Wr\ =\ 0.4 * Rr$ ………………………………………………………………….3.11.10

Experimental work of the material feed requirement calculation for board at 8% urea formaldehyde resin content by using the above equations

$$V = l * w * t$$

Length of mould = 21 cm

Width of board = 21 cm

Thickness of the board =1 cm

The volume can be $V =\ 21 * 21 *\ 1 =\ 441\ cm3$

Then the total material required was calculated using equation 3.2

$$T.m =\ v * \text{p}$$

V = 441 cm^3

Ƿ = 0.75 g/cm^3

The total material required per board was calculated at the moisture contents of 4.13% final oven dry $T.m\ =\ 441 * 0.75 - MC\%\ =\ 316.99\ g$ then the required resin was calculated using equation 3.7

$$(Rr)Perboard = \left(\frac{Pd}{Sc}\right) * Tm,\ + Mc\%$$

Chemical dose per board = say at 8% resin content

Solid contents of (UF) = 60% as given by the supplier

Total material per board 316.99 gram

Moisture contents of solid resin urea formaldehyde (UF) 5.66 %

$$Rr\ = ((0.08/0.6) * 316.99)\ + (42.3)0.056\ =\ 43.69g$$

The hardener could be calculated by using equation 3.8 as shown below

$Wh = (\% \frac{dose}{sc}) * Tm$ Where the sold contents of the hardener was 95%

$$Wh = (2/95) * 316.99 = 6.67\ g$$

Finally it was possible to calculate the required amount of particles and water using equation 3.9 and 3.10 respectively.

$$(Wp) = Tm - (Rr + Wh)$$

$$(Wp) = 316.99 - (43.69. -6.67) = 279.97\ g$$

For both the fine and the coarse layer form ratio of mat forming it was taken that, 40% the fine and 60% for the core layer then

$$WPf = 0.4 * 279.99 = 111.99g$$

$$Wpc = 0.6 * 279.99 = 167.98g$$

111.99g and 167.98g prepared cotton stalk was require per board for the fine and coarse material respectively. Finally the water required was calculated by

$$Wr = 0.4 * Rr$$

Wr = 0.4 *43.69 = 17. 48 g of water was required and the urea formaldehyde was 26.21 gram Her the same calculation was true for other resins of the experiments

3.11 Properties of the Urea Formaldehydes (UF)

During productions of particle board it is important to check some parameters of the resin adhesive properties like viscosity, density, pH, moisture contents and colors, before proceed to mixing. Those properties may have an effect at the quality of the board. The viscosity of the adhesive was cheeked using (AND VIBRO) viscometer by preparing solutions of the formaldehyde with distilled water solution, at the ratios of 30:20 the by taking 40 ml of solution to the viscometer, the result was recorded as 422 mPes at 23.7 ^{o}c which indicates viscos. The pH of the adhesive was also measured using the JENWAY 3505 pH meter with some procedure and have a pH of 8.16 The final parameter was the density of the formaldehyde adhesive also measured suing 10 ml volume measuring cylinder without any external fore and measuring its mass, so it has density of 0.5g/cm^3 and its color is white. All the parameter was in range compering to other earlier studies.

3.12 Mixing

Mixing was blending the well distributed resin, wax, and scavenger on to the particles in the form of droplets. The resin for the coarser and for the fin particle was mixed separately according to the material feed, and manually mixed. During the production all material were calculated and measured separately. The particles, calculated amounts of resin, wax, hardener and water required for each layer, were measured and mixed with mixing time nearly 5 munts and spraying over the particle and mixed well. After completion of spraying to ensure complete mixing of resin and particles checking with occupational health and safety wears, hence it was manually operated. After completion of mixing the mixture was pour in to the rectangular mould and labeled. It was proceed to the production process like mat forming, pressing operations, cooling and trimming.

3.13 Mat Forming and Pressing Operation

A. Mat Forming

Mat forming was making flat mat in mould in multiple layers of three consisting of fine and core layers. According to this work the particle board was three layer with surface top and bottom. The core laying in the center, the top and bottom layers with fine particle of the board. The core layer was made of coarse particles with the classification after oven dried moisture content of the particle less than 4.16 % (P.S.H' ng et.al, 2014.). The effect of surface to core ratio was arranged 4:6 with adhesive range 8%, 11% and 14% dry base of the particle with operating target density of 0.75g/cm^3 and 1cm thickness. The range of the particle size was the coarser (2- 3.5) mm sieve size and the fin particle for the top and bottom layer with range of (1-1.8) mm. was used during mat forming.

B. Pressing Temperature

Pressing temperature was very important for board production hot press. The temperature used to heat the resin and the particle, to penetrate the cell and enter through the particles cell in order to bind well, as a form of steam. Generally the temperature in the ranges of (142 – 189) ^{o}c was used for medium density particle board (Muruganandam et al., 2016). During this experimental work the desired temperature selected 150 o_c, 165 o_c and 180 o_c pre board using heating stove, with the measuring thermometer inserting in the mould by one side and checking every 5 minutes in deferent directions to control the temperature with the temperature allowance of ± 5 ^{o}c.

C. Pressing Operation

In the industrial process hydraulic press is the most efficient form of presses. In this work the hydraulic machine was used for the process production of the board. Where the press applies pressure and bond the activate resin with fiber to change to solid panel. This mechanical hydraulic press has capacity up to 400 bar. In this study, the mat was cold pressed manually first, at constant pressure of 50 bar for 2 minutes before it was heated, Then the well heated mat was pressed using the hydraulic pressing machine with constant pressure 150 bar (Mamza, et,al., 2014) for 10, 15 and 20 minutes pressing time for all board and stay up to the required time to bind well and avoid bond deflection and the curing time may affected with different factors (V.Gadhave, et.al., 2017). Finally the pressure was released and board was produced.

D. Cooling the Board

The well pressed board was out of the mould by pressing with thin metal using the four holes at the back of the mould, then the board was out of the mould carefully and put orderly to cool at a room temperature for more than 3 consecutive days to cool properly and it became strong when it cools with enough time.

E. Trimming the Board

After cooling the board at room temperature, for more than 3 consecutive days, it was proceed to trimming all the boards to get well finished boards trimmed carefully using band saw machine at mechanical laboratory measuring 1cm from each bored and trimmed wall and prepared for testing he quality of the board.

Figure 3-7 Final Trimmed board for test

3.14 Testing the Board

Testing particle board after production was important referring to the standards, the Ethiopian standard, *ES 16983: 2003* was used to check all quality of the bored. Mainly the major and the Mainer tests of the particle board mad from cotton stalk, was investigated farther with conditions of the environments in addition to the functions of the board, for the general purpose and for load bearings (standards for general purpose and heavy load) related to standards. Moisture content (MC), physical and mechanical Properties like Water absorption (WA), thinks swelling (TS), and the modules of elasticity (MOE) in bending strength and bending strength (MOR) internal bonding

(IB) have been evaluated. Parameters that affect the particle boards were too much but for this like particle size, density and pressures were taken as a constant. This evaluation was done in May chew particle board share company, quality department laboratory.

3.15 Moisture content Evaluation of the Board.

During this test, the *ES 16983 2003* test method was used. The air dried particle board sample was prepared cutting from each board with three samples and coded by their production number. The sample was cut from each board with the dimensions of 5 by 5 cm and measured the weight of each specimen and recorded in laboratory data sheet and put in an oven (NPFE 141 Memmert Germany) for 16 hours dried at specified temperature 120^{o}c weighting after drying and recorded in the laboratory data sheets and the result indicated on (Table D-1 Appendix D) was calculated equation (3.11).

- MC% $= \frac{weight\ of\ air\ dry - weight\ of\ oven\ dry}{weight\ of\ air\ dry}$*100……………………(3.11)

3.16 Physical Properties Evaluation of the Board

Testing physical properties of particle board, was done according to *ES 16978: 2003,* mainly for the major tests, in this experimental test the physical Properties, like Water absorption (WA) and thinks swelling (TS) were tested according to Ethiopian standards test methods. Finally evaluated to the Ethiopian standard (ES 16983: 2016) which was mandatory tests for all properties of particle boards.

A. Evaluation of water Absorption (WA)

During this test the particle board (sample) was cut to the desired specimen with dimensions of 2.5 by 2.5 cm according to test method from all particle boards with triplicate samples. Sample was codded according to the production number and parameters. After specimen preparation the mass and the average thickness of all the samples was recorded carefully and soaked in water at room temperature (20 ^{o}c) using water absorption bath first for two hours. After 2 hour immersion time the thickness and the mass recorded in laboratory data sheets two times till it become constant mass and finally socked for 24 hours. Result was calculated using the empirical formulas (3.12)

Water absorption:

- **WA** $= \frac{w\ after - w\ before}{w\ before}$*100, ……………………………………………………(3.12)
- where w is weight of the board

B. Thickens Swelling (TS)

During testing of the thickness, the mass and thickness of original sample was measured and recorded then sample was soaked in water for a period of 2 and 24 hours, then measured the thickness of the soaked sample. The percentage of the thickness was calculated with the equation of (3.13)

- **TS** = $\frac{T\ after - T\ before}{T\ before}$*100, ……………………………………………………….(3.13)

  Where T stands for thickens

Figure 3-8 Experimental set up for (WA) and (TS) test

3.17 Testing the Mechanical Property of the Board

The mechanical properties of the boards can be taken as the bending strength (MOR), elasticity (MOE) and internal bond (IB) were taken as important properties according to the Ethiopian standards identical with *ISO 16984: 2016*. In general those testing parameters were investigated in Maychew particle board factory quality department using universal testing machine (Zwick/ Roell ZMART.PRO Germany).

A. Modules of Elasticity (MOE) in Bending and Bending Strength (MOR)

During this test, sample was prepared according to the desired specimen preparations test method *ES 16978:2003* the universal testing machine. The sample cut with the dimensions of 5 cm by 20 cm, measuring the thickness at four points to calculate the average thickness. Then the volume of each sample was calculated in order to calculate density by measuring mass. Two sample was taken from each board for both the elasticity in bending and bending strength tests at a time. Finally by inserting the basic data like (moisture content, thickness and density) to the computer and adjusting the machine to the desired distance between edges to the applied load. Out-put result was be obtained. For both the modules of rapture and elasticity have the following equations.

- $MOR = \frac{3*P*L}{2*b*d2}$ ………………………………………………………………… (3.14)

Where p, applied load, L, distance b/n edges, b, average thickness and d, depth

Modules of Elasticity (MOE) is the resistance to bending related to stiffness of the board, when the force was applied slowly.

- $\text{MOE} = \frac{l(f2 - f1)}{4*b*t3*(a2-a1)}$ ………………………………………………………… (3.15)

Where f_2-f_1 describes the force increase in the linear elastic part of the force-deflection graph f_1 is the force at 10% of the maximum load, while F_2 40% denotes. The variables a_1 and a_2 are the corresponding deflections to f_1 and f_2 (in MPa).

B. Internal bonding (IB)

In this experimental test the sample was cut with the dimensions of 5 by 5 cm with three sample from each board. Measured their thickness in four direction then calculated average thickens, its volume, density by measuring its mass. Glue stick chemicals used to stick the sample with metal pleats were gotten from May chew particle board company. The metal plates found in the laboratory, was used to hold the specimens stick. During this laboratory work the glue was cut with the size of 3 cm and inserted in oven at the temperature of 125^{o}c in order to melt and lubricate to the metal pleat. Then the sample of the board was attached to it, and cooled. Then feeding the necessary data to the computer test was evaluated using universal testing Machen to see the bonding by pulling apart and recorded the data in computer the date of each sample was registered carefully for analysis some experimental setup was shown in Figure 3.9, and result was calculated Using equation.

$Ft = F\,max\,/\,ab$………………………………………………………………….. (3.16)

The bonding strength perpendicular to the plane of the panel of each test piece, Ft, perpendicular, expressed in (MPa) in two decimals.

Where

F max is the breaking load, in newton (N)

a is the length of the test piece in (mm)

b is the width of the test piece, in (mm)

As showed on Figure 3-9, the experimental setup for quality test starts form density determination and next the moisture contents because these two parameters are important for the determinations of the mechanical properties of the qualities of each board.

Figure 3-9 Experimental setup for bending strength and internal bonding test

4. RESULET AND DESCUSSION

4.1 Analysis of Cotton Stalk Morphology, Proximate and Chemical compositions

4.1.1 Analysis of Morphological Structure of Cotton Stalk

According to anatomical study the cell wall thickness, lumen diameter, fiber length and width are important parameters for the determination of the morphological structure of the cotton stalk. This was used to compare particle boards made form hard wood. The analysis showed that the maximum average value of the lumen diameter and cell well thickness were 45.3 µm and 11.3 µm respectively for 60 cells. Parameters lumen diameter and cell well thickness their value listed in Table A-1 Appendix A are important to determine the slenderness ratio. Cell walls mainly consist of cellulose, hemicellulose, and lignin in a 4:3:3 ratio, This ratio differs from sources such as hardwood and softwood (Mark Hughes, 2016). Carefully observing using the Moitic microscope there was gap between the cells like hard woods. The cell wall was a composite made of different layers and elements. These are fine thread like microscopic elements, which in turn made of micro fibril (Fahmy et al., 2017). These elements are arranged in different patterns in the secondary cell wall. The mechanical properties of a board increment perhaps was due to the higher specific surface and more slenderness ratio important to attain higher strengths of board. irrespective of the type of wood particles used (Kord, et.al 2016) Figure 4.1 indicates Microscopic image of lumen diameter and cell thickness using (Mo tic image plus 2.0 software).

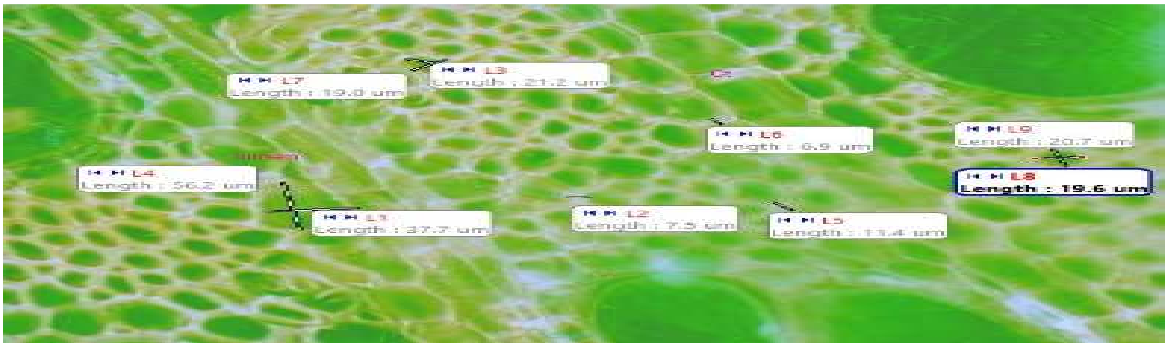

Figure 4-1 Microscopic image of cell well and lumen diameter of cotton stalk

As shown on the figure 4.2 other important parameters that were analyzed using Moitic image plus 2 software was fiber length and width, have average values for 60 fibers were 0.33 mm and 5.96 µm respectively. From careful observation the fiber was clearly observed slightly thick. According to different studies the thickness of Cotton stalks fibers was thicker than those of same non-woods, and soft wood fibers. The fiber depends on the cellulose content and the spiral angle which bands on micro fibers in the inner secondary cell wall Compering to the hard woods like acacia and eqlaupites trees (Indrayani, et.al., 2015)(Nkomo, et,al, 2016). In general cotton stalk has good fiber contents that can be used for industrial purposes (P. G. Patil, 2007).

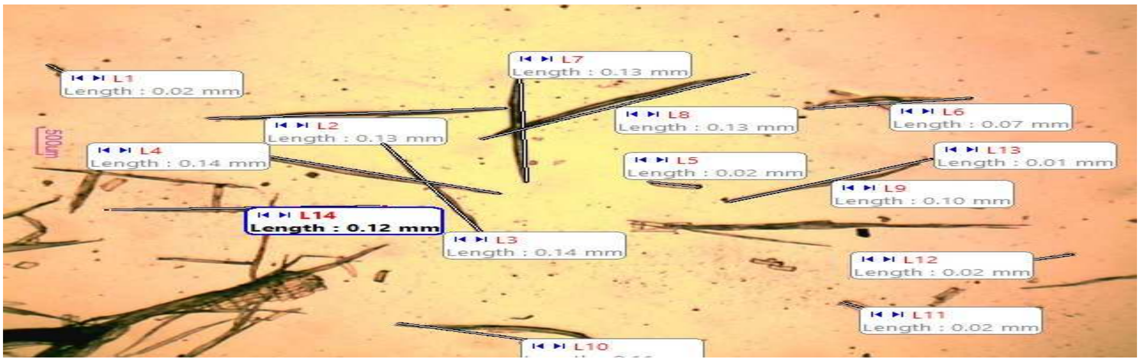

Figure 4-2 Microscopic image of fiber length and width of cotton stalk

4.1.2 Chemical Composition Analysis of Cotton Stalk

Figure 4.3 shows that the chemical compositions of cotton stalk like cellulose, lignin, hemicellulose, alcohol benzene extract, hot and cold water solubility was determined and their average results were 39.32 %, 24.30 %, 11.07 %, 3.74 %, 9.68 % and 11.89 % respectively. The experimental results were shown on Table B-1-B-6 Appendix B. This result shows comparable chemical compositions with lignocellulose and hard woods. According to (Zhaoxia Liu., et al., 2018). Hard woods have chemical compositions, cellulose (38-50) %, lignin (30-35) %, hemicellulose (14-20) % solubility (4-6) % and extractive (2-6) %. This shows the cotton stalk has highest cellulose and lignin contents relative to other crops residues. Sine experimental result for the chemical composition of cotton stalk is comparable to the literature values then it is better to use it as alternative raw material for particle board productions

The other main chemical composition was the hemicellulose hot and cold water solubility and extracts of the cotton stalk, which indicts very high for all of them, this has an effect on the final products because, except the hemicellulos the others like, both hot and cold water solubility, and the extract was higher than hard woods and same softwoods. But higher solubility and extractive can affect the resin compering to hard woods. This may affect the quality of the final product at the end. Cellulose and lignin were the main structural component that provide strength and stability to the plant cell wells and fibers. The amount of cellulose and lignin in a fiber influences the properties, fiber production and the utility of the fiber for industrial applications (Narendra Reddy, 2005).

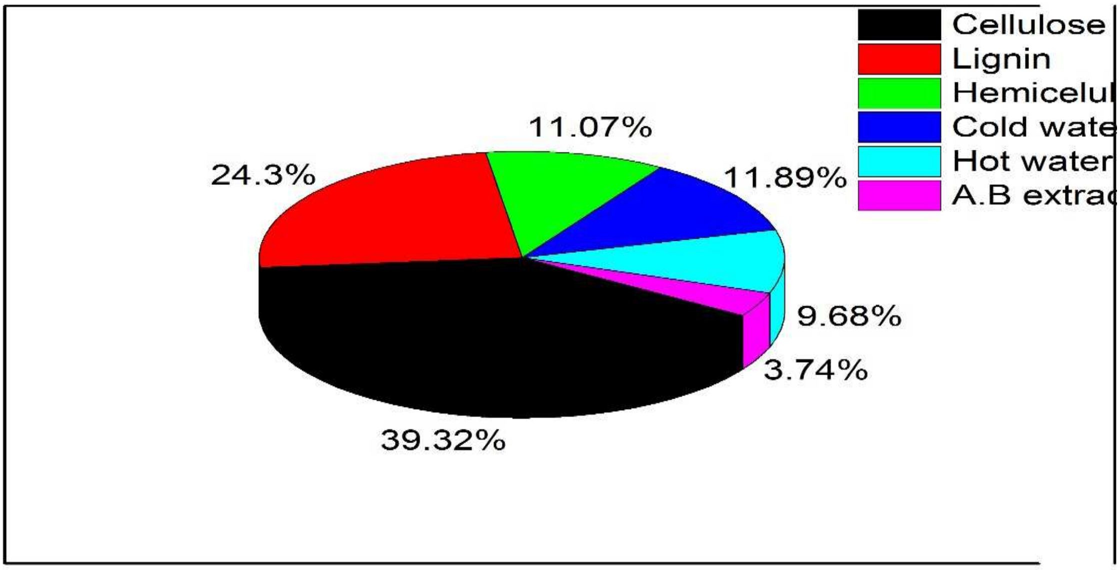

Figure 4-3 Chemical composition of cotton stalk

4.1.3 Proximate Analysis of cotton stalk

A. Ash and Moisture Content Analysis

Ash and moisture contents are important parameters for the selection of wood materials for industrial purposes and their experimental result was 2.82 % and 4.16 % respectively as showed in Table C -1and C-2 Appendix C. The ash content was very low but high compared to hard woods due to up take of inorganic impurities and it is very low compared to other lignocellulose woods. The low ash content of the stalk shows that its carbon content is high.

On the other hand the moisture contents for lignocellulos and hard woods used for production of particle board was in the range of mostly from 2-5% oven dry moisture (Fahmy et al., 2017). The cotton stalk has desirable moisture content according to the experimental result. So it was related to the raw material standard limits of the moisture contents of the raw material before production.

4.1.4 Fourier Transform Infra-Red (FTIR) spectroscopy

Further analysis on presence of functional groups on the surface of the cotton stalk was analyzed using Fourier transform infrared spectroscopy.

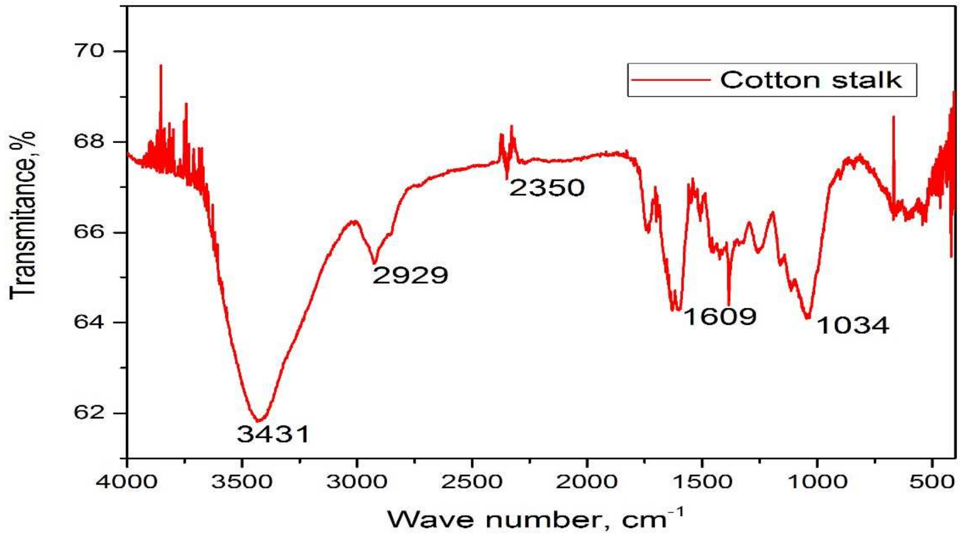

Figure 4-4 FT-IR spectra of raw cotton stalk at 400-4000 wave number

As shown in figure 4.4 cotton stalk has comparable functional group as wood palps. This can help for wood materials to know at what range the chemical composition would lay and to what rang stretched as earlier study show that the peak at around 3431cm^{-1}indicates -OH grope represents either cellulose or lignin at the vast wave number (Sultan et al., 2017) The peaks at around 2929-2920cm^{-1}repersents the C-H groups symmetrical stretching in aliphatic methyl (Gbremedhin Teket, 2017) (Sultan et al., 2017). The peak appears at around 1634-1609 was due to ester carbonyl stretching absorption bond mainly arises from the carbonyl group stretch in un conjugated ester carboxylic or ketone group in hemicellulose that can effect on the quality of the raw material.

4.1.5 Analysis Teste of the Particle Board Produced

4.1.5.1. Analysis of Mechanical Property of the Board

Mechanical properties illustrates the modules of rapture (MOR), modules of elasticity (MOE) and internal bonding (IB). All the boards were tested according to Ethiopian test method standard ES 16978: 2003 the mechanical properties of wood based Panels was important quality parameters like the physical tests. According to this study values of the experimental panels from cotton stalk was tested and analyzed. All the results were compared to the Ethiopian standard ES 16893: 2016 wood based panel – particle board mainly for general purposes.

A. Modules Elasticity (MOE) in Bending and Bending Strength (MOR)

Bending strength and elasticity were the quality assurance parameters. Bending strength was the braking strength of a board when a force was applied immediately. Modules of elasticity is the resistance related to stiffness of the board slowly. The experimental result was compared to the standard the range of thickness selected from 6 mm to13 mm was taken as reference to the produce experimental product 10 mm thickness as reference. The maximum result for the modules of rupture (MOR) and elasticity (MOE) were 11.58 and MPa and 2259.2 MPa respectively, and the minimum values determined for panels 7.45 MPa and 1085.0 MPa as shown in Table 4.1. The result indicated that the significant differences between panels average result, for the rupture (MOR) and elasticity (MOE). The values of modules of rapture (MOR) and modules of elasticity (MOE) initially increased at factor of hot pressing time 10 minutes, and then start to decrease when pressing time was over 15 minutes. The maximum modules of strength (MOR) and modules of elasticity were observed at hot pressing of 11% resin content and at pressing temperature of 150 ^{o}c for 10 minutes of hot pressing time. The lowest modules of rapture (MOR) and modules of elasticity (MOE) occurred at 8% resin content and 20 minutes, and 180 ^{o}c. The values for the mechanical properties were large at the pressing time of 10 – 15 minutes and pressing temperature range 150 -165 ^{o}c in this experimental work. The values decrease for larger temperature and long pressing time. For the temperature values greater than 165 ^{o}c and starts to lose its bonding strength. Therefore, the mechanical properties decreased when the pressing time was too long due to the following reasons. According (Chen et al., 2015) hemicellulose, cellulose, and lignin are the primary material affecting the mechanical properties of the boards. When the temperature reaches above 170 ^{o}c with long pressing time. Hemicellulose begins to degrade, whereas cellulose and lignin are less affected under high temperature, due to their different structures and components. Therefore the values of rupture, and elasticity of the boards increased with increasing hot pressing temperature up to 165^{o}c only for cotton stalk board. However, the adhesive penetrate the cells as a form of stem could cure excessively if hot pressing temperature is too high. The cells of the stalk, start to degrade or decompose and decrease the values of mechanical properties *(Lei et al. 2014)*.

Bending strength and elasticity was affected by the geometry of particle may substantially affect the quality of bonding among particles a consequently influence the strength and stiffness of the manufactured boards generally on mechanical properties *(Juliana et al. 2012)*. Thinner and longer particle would give a higher aspect ratio, hence provides larger contact areas between the particles, as compared to thicker and shorter particle. Regular wood chips used for particle board production have better mechanical characteristics compared to particle boards manufactured from lignocellulose wood chips. Because of material variation and geometry of particles *(Of et al., 2012)***.**

Generally according to the Ethiopian standards 2016 the minimum requirements for modules of rupture (MOR) and elasticity (MOR) was 10.5 MPa and 1600 MPa respectively, Boards for general purposes or for general uses and interior fitments (including furniture), while most of the board produced could meet the standards which meets the minimum requirement for modules of rupture (MOR) and elasticity (MOR).

Table 4-1 Final average result test of strength (MOR) and elasticity (MOE)

Run nu	**Sample code**	**Average Thickness In cm**	**Support separation In cm**	**Average density in g/cm^3**	**Average Moisture In (%)**	**MOR (MPa)**	**MOE (MPa)**
1	14/20/165	0.86	15	0.83	6.53	10.16	1815.516
2	8/20/165	0.97	15	0.71	6.45	8.2	1058.302
3	11/20/150	0.91	15	0.75	7.16	10.8	1966.65
4	11/15/165	0.86	15	0.74	6.96	10.22	2055.485
5	8/15/180	0.95	15	0.72	6.9	7.45	1535.317
6	11/10/150	0.89	15	0.76	7.1	11.58	2259.107
7	14/15/180	1.02	15	0.7	6.64	9.01	1865.516
8	14/15/150	0.89	15	0.72	6.7	11.45	1646.663
9	8/15/150	0.93	15	0.7	6.0	9.73	1631.45
10	8/10/165	0.93	15	0.71	7.72	9.12	1547.301
11	11/15/165	0.88	15	0.76	6.96	10.04	2232.602
12	11/10/180	0.855	15	0.72	7.0	9.41	1260.865
13	11/15/165	0.87	15	0.74	7.82	10.21	1814.903
14	11/20/180	0.93	15	0.66	7.12	9.04	2159.771
15	11/15/165	0.92	15	0.71	7.1	10.22	1683.492
16	14/10/165	0.86	15	0.8	7.5	11.02	1780.516
17	11/15/165	0.915	15	0.71	7.6	10.11	1610.184
Maximum						**11.58**	**2259.107**
Minimum						**7.45**	**1058.302**

B. Analysis of Internal bonding (IB) Board

Internal bonding is measure of the board integrity, how well bonded to gather. It was investigated using piece of sample board and pulled apart with tension, to both face. It was important for the qualitative characterization of the particleboards. The internal bonding (IB) of the boards was maximum for 10 minutes 150 ^{o}c and 11 % resin content and minimum for 20 minutes pressing time and 180 ^{o}c at 8 % resin content. The experimental values were 0.58 MPa and 0.26 MPa respectively. This was due to the resin adhesives and pressing temperature, heat can transmitted from the surface of the mat to the center as sores of steam. The resin penetrates thoroughly and bonded well. But decreased after certain range of hot pressing temperature and time. Internal boning was affected by density, chemical dose, particle size and types of raw material and other factors. Cotton stalks cell could deformed with increasing pressing time and high temperature, even if the adhesive need enough time to cure to bind the stalks together (Kord et al., 2016). Additionally when the density increases, the needed pressing pressure on the board increased, leading to a larger internal stress and a higher spring-back, this might destroy the adhesive line structure in the inner part of the board and weaken the adhesion between the stalks requires greater requirements pressure for the pressing machine (Amenaghawon, 2015)(Chen et al., 2015).

According to Ethiopian standard test method 16984 the minimal requirement of internal bond strength for general purpose, interior fitments and load-bearing boards, were 0. 24, 0.35 and 0.50 MPa, respectively. Almost all particleboards produced was meet the minimum and maximum requirement for general uses and for interior fitments, as shown in Table 4.2.

Table 4-2 Final average result test of internal bonding (IB)

Run nu	Sample code	Mass in (g)	A. Thickness in (cm)	A. density in g/cm^3	A. M.C in (%)	IB (MPa)
1	14/20/165	17.12	0.91	0.76	6.53	0.44
2	8/20/165	16.14	0.844	0.77	6.45	0.36
3	11/20/150	17.35	1.01	0.63	7.16	0.38
4	11/15/165	15.78	0.923	0.69	6.96	0.44
5	8/15/180	15.17	0.935	0.705	6.9	0.34
6	11/10/150	17.96	0.815	0.81	7.1	0.45
7	14/15/180	15.99	0.987	0.972	6.64	0.29
8	14/15/150	17.67	0.86	0.645	6.7	0.54

9	8/15/150	17.96	0.85	0.81	6.0	0.30
10	8/10/165	16.22	0.923	0.66	7.72	0.43
11	11/15/165	17.01	0.82	0.769	6.96	0.46
12	11/10/180	15.54	0.85	0.73	7.0	0.31
13	11/15/165	17.57	0.914	0.629	7.82	0.44
14	11/20/180	15.27	0.904	0.769	7.12	0.26
15	11/15/165	16.01	0.93	0.629	7.1	0.46
16	14/10/165	17.26	0.802	0.86	7.5	0.51
17	11/15/165	16.81	1.01	0.645	7.6	0.41
Maximum						**0.54**
Minimum						**0.26**

Where A is average and MC is moisture contents

4.1.6. Moisture content Evaluation

Evaluation of Moisture content of the board was important for different uses, and according to Ethiopian standard test method 16979 the moisture contents must be in the ranges of (4 up to 12) %. For commercial purposes, that all experimental produced boards were in between this ranges with the results of minimum 6% and maximum 7.82 % this indicates that the moisture content meets the standard. But the board has oven dried moisture content variation from board at an average of 1.82 % from the maximum and minimum, vales. This shows an increments due to the adhesive during production of the board. As shown on the Figure 4.5 blow the moisture contents variation was not high. Different studies shows that Moisture content with low variation per panel enables greater reliability with regard to the results obtained. Moisture and specific mass, especially, influence significantly the physical-mechanical properties of the particleboards (Melo et al., 2014). In general this verified variations not high as showed in Table D-1 Appendix D. the moisture content was important to test the mechanical properties.

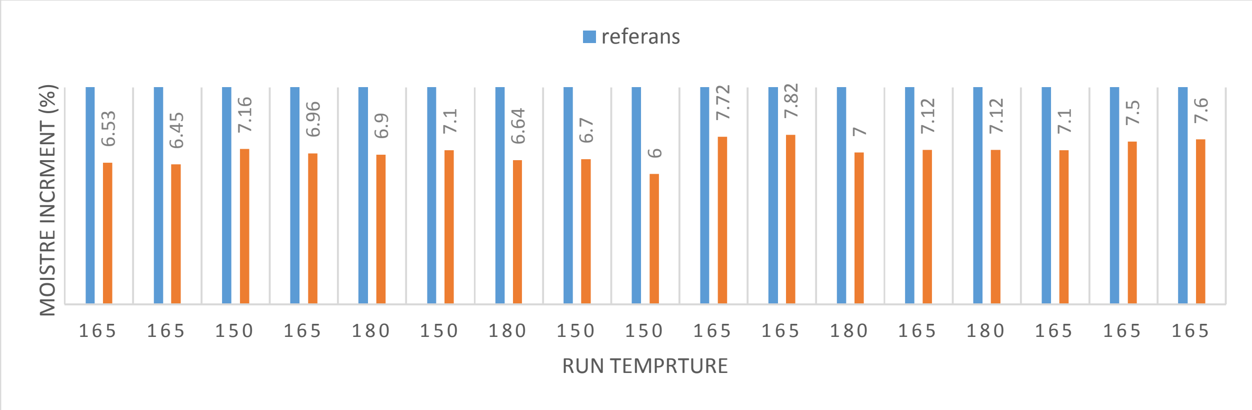

Figure 4-5 Moisture content evaluation of the board

4.1.7 Analysis of physical properties of the board

4.1.7.1. Analysis of water absorption (WA) and Thickness Swelling (TS)

The water absorptions and thickens swelling are important parametric testes on wood particle boards, according to Ethiopian standards. The two parameters were used to determine the short and long term absorption and thickness swelling. After experimentally produced the Cotton stalk particle board was tested for 2 and 24-hours of water immersion time. The average values of thickness swelling (TS) and water absorption (WA) were increased from 67.9% to 75.4% for thickness swelling and form 122.7% to 129.7% for 2 to 24-hours of water immersion time for water absorption as showed in Table D - 5 Appendix D.

The cotton stalk particle board thickness swelling exceeds 50.4 % compared to standards, this shows the particle board absorbs water immediately after it was soaked in water as shown the difference in Figure 4.6. This was related to lower density, bigger particle size and high porosity of the cells of the cotton stalk and the board in comparison to industrial wood particles, for water uptake, this can lower the strength of the board *(Muruganandam et al., 2016).* The particles were very short and constituted at high percentage of total fiber content, thus, creating a very large and highly absorbent surface area *(Amenaghawon, 2015).* The other reason may be the cotton stalk chemical compositions the extractive, solubility and hemicellulose was high compared to hard woods. Hemicellulose was water soluble components and have a peeling reaction under mild alkaline conditions and high temperature, it would have alkaline hydrolysis (H. Chen, 2014*).*

The other effect may according to pH value with the binders' One of the most important chemical properties of bio-based fibers that have an important role inequality of pH value of raw material and binder can lead into different water absorption properties, cotton stalk has pH of 4.74, and hard woods 5.96 *(Hossein Khanjanzadeh et, al., 2012).*

Generally according to standards for dry condition of heavy load bearing particle board ES 16983 test method was not more than 25% for 24 hours thickness swelling. All boards did not satisfy the standards for water absorption and thickness swelling as showed on Figure 4.6 and 4.7 respectively.

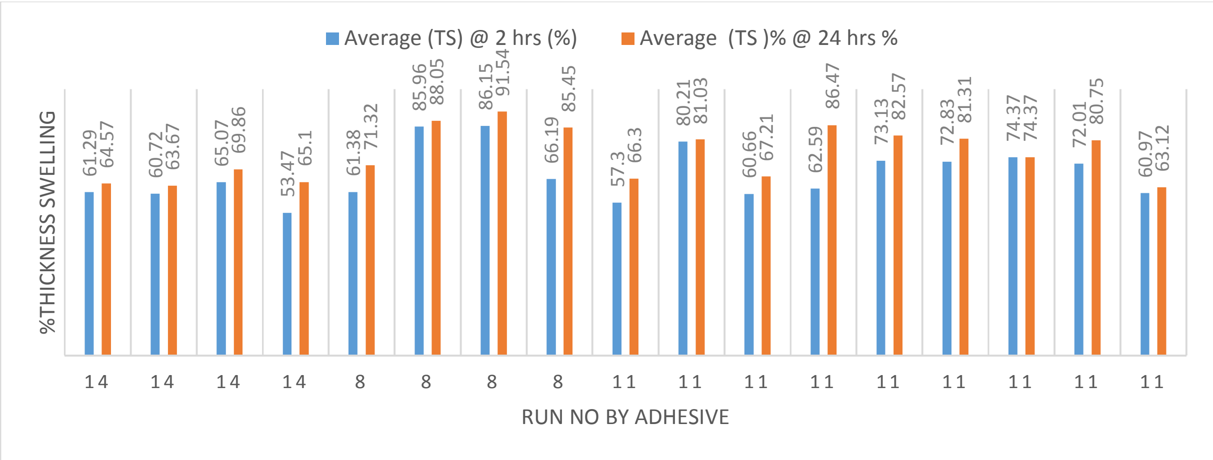

Figure 4-6 Thickness swelling chart for 2 and 24 hours

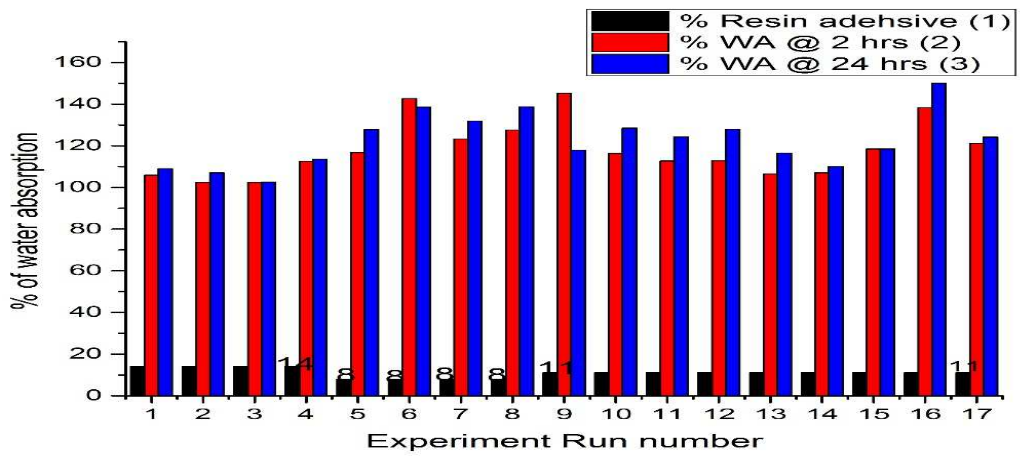

Figure 4-7 Water absorption chart for 2 and 24 hours

4.2. Performance of Hot Press Particle Board Production

Further investigation on the particle board quality was performed. This work was carried out with maximum of 400 g capacity per board with constant 15 MPa hydraulic press. The temperature, adhesive ratio and hot pressing time was adjusted to the desired conditions. The statistical analysis of the board quality is discussed in the following sections.

4.2.1 Statistical Analysis on Factors Affecting Degree of Production on Qualities of the Board

The experimental design selected for this study is Box Behnken design (BBD) and the response variable measured is the two mechanical properties (MOR) modules of rupture and (IB) internal bonding using the commonly experimental design (BBD) for three level and three factor experiments. Box and behnken proposed three level design for fitting response surface formed by combining 2^k factorials with in complete block design and 5 center points was used in the optimization study a total of 17 experiments were conducted, where k is three for three factor (independent variables) used in the analysis. Three production process are time, temperature and adhesive dose. The BBD always have three levels for each factor and are proposed built to fit different model. BBD does not have runs at the extreme combinations of all the factors, but compensates by having better prediction precision in the center of the factor space. While a run or two can be abortive in these design the accuracy of the observations in the remaining runs is critical to the dependability of the model.

Design expert software 7.0.0 was used in the least squares regression analysis of variance (ANOVA). This statistical software program is used to generate the model equation, interaction effects of the independent variable and surface plots using the fitted equation obtained from the regression analysis holding one of the independent variables constant. BBD conditioned and their respective response and the ANOVA are given on table 4.3.The test for quality of the board was made using the universal testing machine, and the detail calculations and results were discussed.

Table 4-3 Experimental and predated values

Run no	Chemical dose (%)	pressing time (minutes)	pressing temperature (ºc)	Experimental MOR in (MPa)	Experimental IB in (MPa)	Predicated MOR in (MPa)	Predicated IB in (MPa)	Residuals MOR in (MPa)	Residuals IB in (MPa)
1	14.00	20.00	165.00	10.16	0.44	10.17	0.45	-0.01	-0.010
2	8.00	20.00	165.00	8.2	0.36	8.35	0.36	-0.15	-0.003
3	11.00	20.00	150.00	10.8	0.38	10.82	0.39	-0.02	0.010
4	11.00	15.00	165.00	10.22	0.44	10.16	0.44	0.058	0.001
5	8.00	15.00	180.00	7.45	0.34	7.48	0.33	-0.03	0.011
6	11.00	10.00	150.00	11.58	0.45	11.76	0.45	-0.18	0.000
7	14.00	15.00	180.00	9.01	0.29	9.18	0.27	-0.17	0.019
8	14.00	15.00	150.00	11.45	0.54	11.42	0.53	0.03	0.01
9	8.00	15.00	150.00	9.73	0.30	9.56	0.30	0.17	-0.001
10	8.00	10.00	165.00	9.12	0.43	9.11	0.43	0.01	0.02
11	11.00	15.00	165.00	10.04	0.46	10.16	0.44	-0.12	0.21
12	11.00	10.00	180.00	9.41	0.31	9.39	0.33	0.02	-0.002
13	11.00	15.00	165.00	10.22	0.44	10.16	0.44	0.058	0.001
14	11.00	20.00	180.00	9.04	0.26	8.86	0.27	0.18	-0.01
15	11.00	15.00	165.00	10.22	0.46	10.16	0.44	0.058	0.021
16	14.00	10.00	165.00	11.02	0.51	10.87	0.52	0.15	-0.01
17	11.00	15.00	165.00	10.11	0.41	10.16	0.44	-0.05	-0.029

4.2.3. Regression model equation

The model equation that correlates the response (modules of rupture and internal bonding) to the quality of the board process variables of the actual value after excluding the insignificant terms were given blow final equation in terms of coded factors for both the modules of rupture and internal bonding were given in equation 4.1 and 4.2 respectively.

$$MOR\ (MPa) = 10.18 + 0.89 * A - 0.37 * B - 1.08 * C - 0.66 * A^2 \quad \ldots\ldots 4.1.$$

And for the internal bonding can be…..

$$IB = 0.44 + 0.044 * A - 0.032 * B - 0.059 * C - 0.073 * A * C - 0.080 * C^2 \quad \ldots\ldots 4.2$$

Where A is chemical adhesive (%), B is pressing time in minutes and C is pressing temperature in ^{o}c.

4.2.4. Model Adequacy Check

The regression model was significant with correlation coefficients of determination of R-squared, adjusted R-squared and predicted R-squared having a values 0.9896, 0.9763 and 0.8549 for modules of rupture (MOR) and 0.9720, 0.9551 and 0.9055 for internal bonding (IB) respectively. The quality of these model developed could be evaluated from their coefficients of correlations for both, the modules of rupture (MOR) and internal bonding (IB) have R-squared values for the developed correlations were 0.9896 and 0.9720 respectively, which implies 98.96% for the rupture and 97.2% for the internal bonding of the total variation on the quality test of the board was accredited to the experimental study.

The graph of the predicted value obtained using the developed correlation versus actual values was shown in Figure 4.8 and 4.9. The results was demonstrated that the regression model equation provided accurate description of the experimental data, for both the modules strength and internal bonding, which all the points are close to the line of perfect fit. This result indicates that it was successful in capturing the correlation between the three production process variables to the quality of the board. The adequacy of the model was further checked with analysis of variance (ANOVA) as shown on Table 4.2 based on a 95% confidence level, F – value is a test for comparing model variance with residual (error) variance. If the variances are close to the same, the ratio will be close to one and it is likely that any of the factors have a significant effect on the response with the P – value less than 0.05. It is calculated by model mean square divided by residual mean square. The Model F-value of the modules of rapture and internal bonding could be 74.15 and 57.77 implies the model is significant. There is only a 0.01% chance that a "Model F Value" this large could occur due to personal error or disturbance for both.

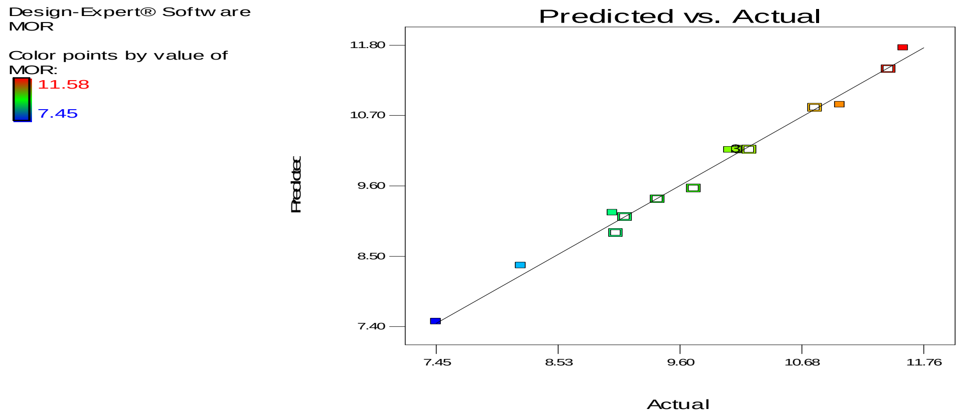

Figure 4-8 Predicted verses actual value of bending strength of the board for (MOR)

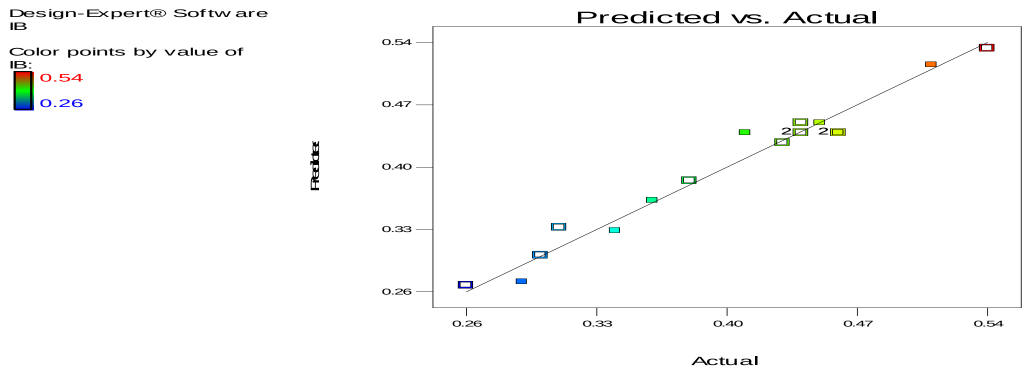

Figure 4-9 Predicted verses actual value for internal bond strength of the board for (IB)

Table 4-4 ANOVA for the regression model equation and coefficients for rupture (MO*R*)

Source	**Sum of squares**	**DF**	**Mean square**	**F- value**	**Prob> F**	**Remark**
Model	18.82	9	2.09	74.15	< 0.0001	a
A-chemical dose	6.37	1	6.37	226.02	< 0.0001	a
B-pressing time	1.07	1	1.07	38.06	0.0005	b
C- temperature	9.35	1	9.35	331.74	< 0.0001	a
A^2	1.87	1	1.87	66.49	< 0.0001	a
Residual	0.20	7	0.028			
Lack of Fit	0.17	3	0.057	8.17	0.0351	not significant
Pure Error	0.028	4	6.920E-003			
Cor Total	19.01	16				

Note [b] is significant and [a] means highly significant and

Table 4-5 ANOVA for the regression model equation and coefficients for internal bonding (IB)

source	Sum of squares	DF	Mean square	F- value	P –value Prob> F	Remark
Model	0.100	6	0.017	57.77	< 0.0001	a
A-chemical dose	0.015	1	0.015	53.24	< 0.0001	a
B-pressing time	0.0085	1	8.450E-003	29.38	0.0003	b
C- temperature	0.028	1	0.028	96.00	< 0.0001	a
AC	0.021	1	0.021	73.10	< 0.0001	a
C^2	0.027	1	0.027	94.56	< 0.0001	a
Residual	0.0029	10	2.876E-004			
Lack of Fit	0.0012	6	1.994E-004	0.47	0.8020	not significant
Pure Error	0.0019	4	4.200E-004			
Cor Total	0.10	16				

Note [b] is significant and [a] means highly significant and [c] not significant

From the regression model of table 4.5 and 4.6 both the Modules of Rupture and Internal Bonding values of " prob > F " less than 0.0500 indicates the model terms are significant. In this case for the Modules of Rupture (MOR) A, B, C, A^2 and Internal Bonding A, B, C, AC, C^2 are significant model terms. Values greterthan 0.100 indicates the model terms are not significant. This shows the amount of chemical adehesives, pressing time, pressing temperature and the chemical adehesives squar for the modules of rupiture and amount of adhesive, presing time, adhesive times pressing temepereture and square of pressing time for the internal bond, can afect the qulity of the board significantily.

The "lack of fit F-valu" that 8.17 for modules of rupiture and 0.47 for internal bonding implies lack of fit is not significant relative to the pure error. There is 3.5 % and 80.2 % chance that "lack fit" for both this large could occre due to noise. Non significant lack of fitis good, both the modle shoud fit.

4.3 Effects of Process Variable on the Qulity of the Board

Besed on the analyisi of variance the quality of the board was significantly afected by various interactions betewen the process variabls. This result demonstrated that the advanteg of using BBD surface ressponse for expermental data analysis holding the interactions effect between variables that afect the strength of the board. In adition to interaction effct, individul significant process variables that afect the quality of the board pesing time (B) and pressing tempratue (C) for MOR and pressing time for internal boniding (B)

4.3.1 Effect of Individual Process Variables

From the Figure 4.10 the quality of the board was significantly affected by the variable of pressing duration and temperature for its strength, both the pressing temperature and pressing time were maximum at the initial point, but the quality of the board starts to drops immediately when the pressing time and temperature starts to increase the initial points for the modules of rupture. According to (Chen et al., 2015.) Such behavior could be shown the cells, and hemicellulos continents of the stalk as the temperature and pressing time increases the cells of the stalk will deformed by long press and as the temperature increase the adhesives will cure but the hemicellulos will degrade so the mechanical properties of the board will decrease. The other was the internal bonding of the board as shown on Figure 4.10, as the pressing time increases the adhesives will penetrate in to the cells and glued well, but by using long pressing time stalk will start to degrade which affects the quality of the board, reducing its bonding strength. On the other hand the strength of the board could be increasing for both with increasing of the chemical concentrations of the adhesives.

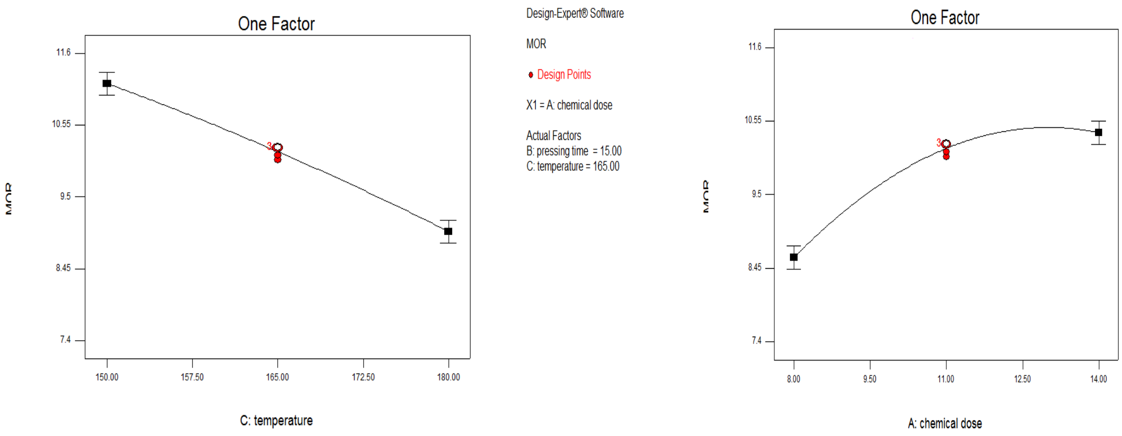

Figure 4-10 The strength of the bored at temperature at resin contents 11% and pressing time 15 minutes and resin content for time of 15 minutes and pressing temperature 165 ^{o}c at the right for modules of strength (MOR) respectively.

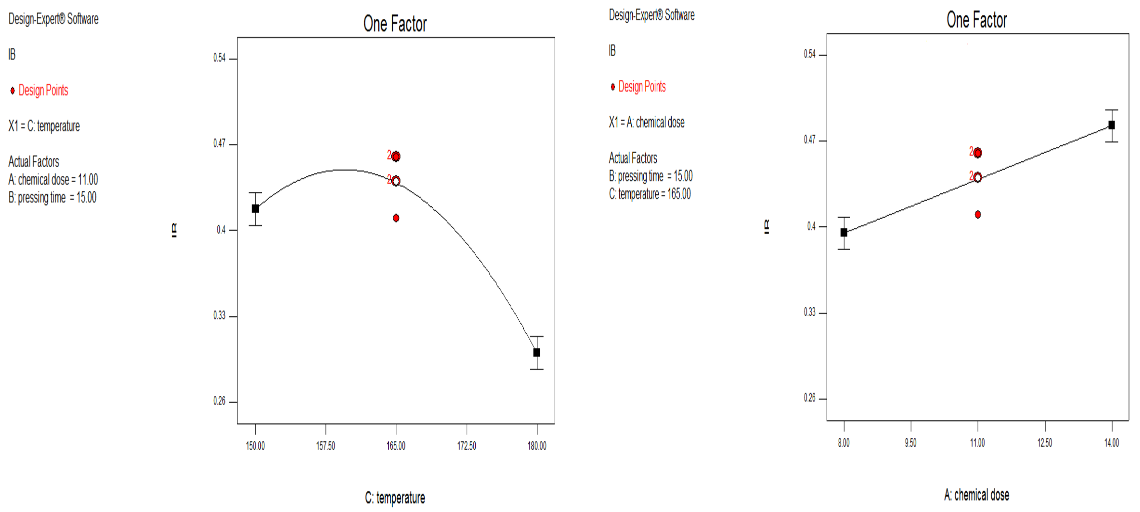

Figure 4-11 The strength of the bored at constant resin contents 11% and pressing time 15 minutes and at constant time of 15 minutes and pressing temperature 165 ^{o}c for internal bond (IB) respectively.

4.3.2 Effect of Interaction between Process Variables

The common way to summarize the results of a Box Behnken design experiment was, in the form of response surface plot and via response contours plot. The process variables were found to have significant interaction effects in Figure 4.12 up to 4.19 shows the interaction between temperature adhesive concentration and pressing time for the quality of the board respectively.

In general as the chemical adhesive increase both for the modules of rupture and internal bonding increases. From the three interaction effects shown in the Figures 4.14 and 4.19 contour at lower range of pressing time and lower range of pressing temperature but at high chemical adhesive the boards have the highest quality in other words the cotton stalk board can be good at lower pressing time and temperature but high adhesive ratio will give good quality boards.

Another observation is that, at higher pressing temperature and duration range of the production process observations showed that is not beneficial in the quality of the board. This is because at the process condition high adhesive and less temperature is sufficient at less pressing time. This phenomena further supported by the fact that the chemical adhesive is the most significant process variable that affect both responses or quality of the board, that indicated by highest f-value in the ANOVA as shown on Table 4.4 and 4.5 respectively. The response surface Methodology (RSM) was used to optimize the condition of quality of the board and interactions of the factors affecting the productions.

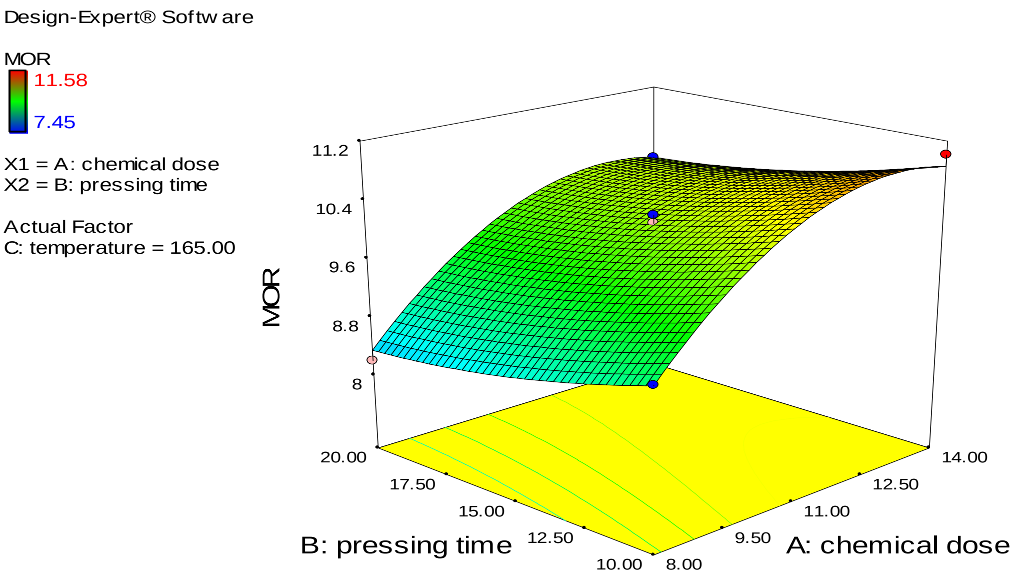

Figure 4-12: Surface plot of the inter action effect of chemical dose adhesive to pressing time versus modules of rapture when the pressing temperature was 165 °c

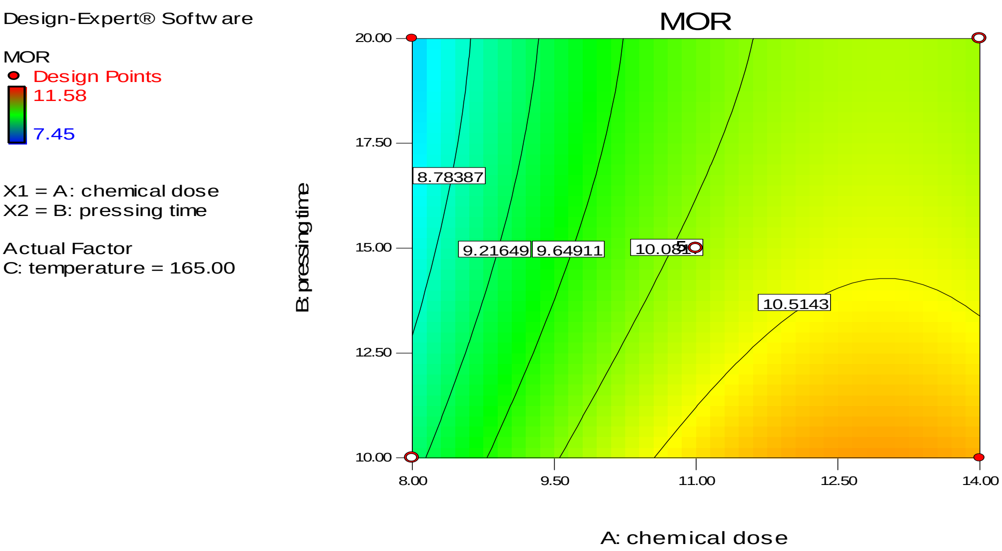

Figure 4-13 Contour plot of the interaction effect of chemical dose adhesive to pressing temperature versus modules of rapture when the pressing temperature 165 °c

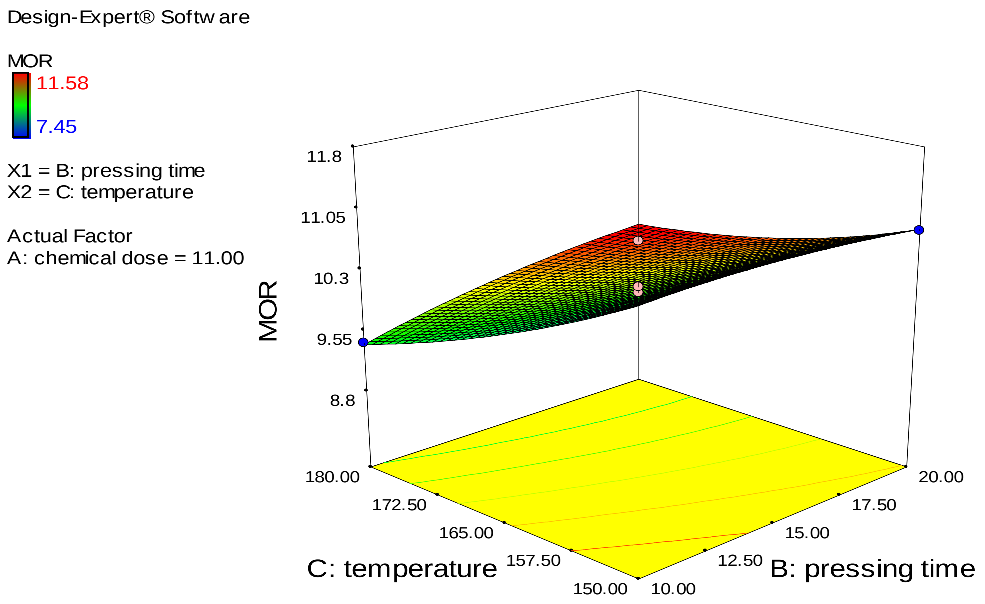

Figure 4-14 Surface plot of the inter action effect pressing time and pressing temperature versus modules of rupture for chemical adhesives 11%

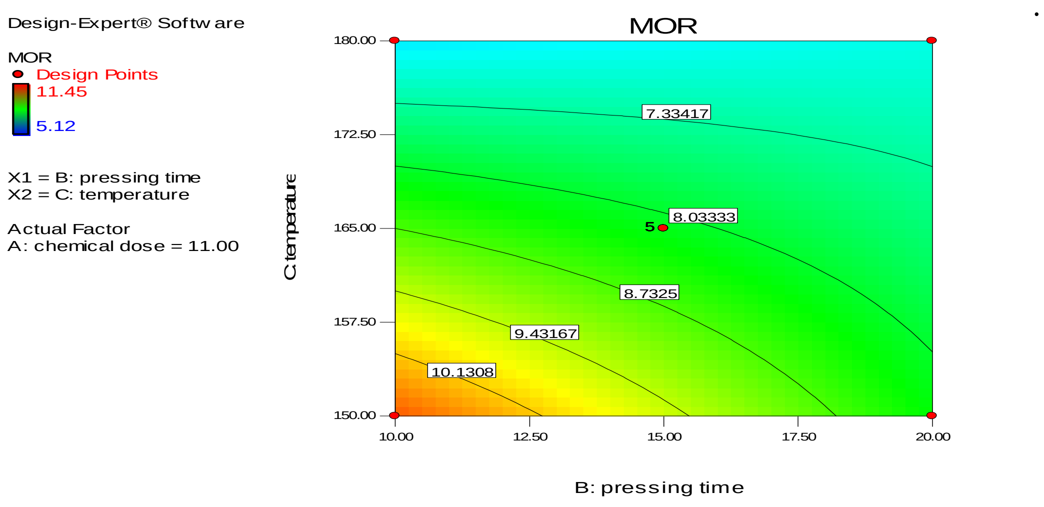

Figure 4-15 Contour plot of the inter action effect pressing time and pressing temperature versus modules of rupture for chemical adhesives 11%

Figre 4.12 shows the interaction effect presing time and temprture to the modules of rupiure shows reletivly lower modules of rapitur at highr pressing time dueto the dgrade of cells of the stalk and dicomposition of the hemicelulose. On other hand Figure 4.13 the interaction effect of chemical adhesive to presing temperature versus modules increases with incersing the resin adhecives at the intial temprture. Addiionaly the possible response to the quality of the board was internal boniding of the board to see the interaction effectes of the porcess variables on the following steps.

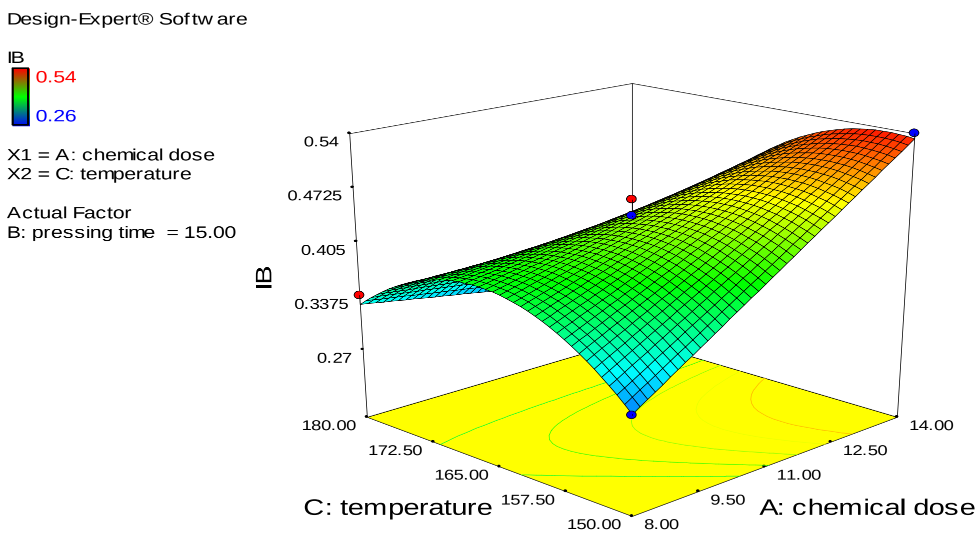

Figure 4-16 Surface plot of the inter action effect of chemical dose adhesive to pressing temperature versus internal bonding for pressing time 15 minute.

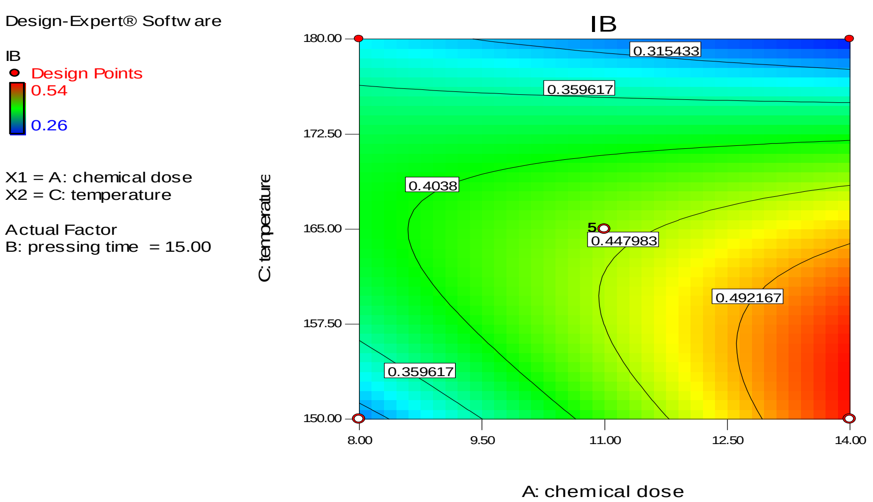

Figure 4-17 contour plot of the interaction effect of chemical dose adhesive to pressing temperature versus internal bonding when the pressing time 15 minutes.

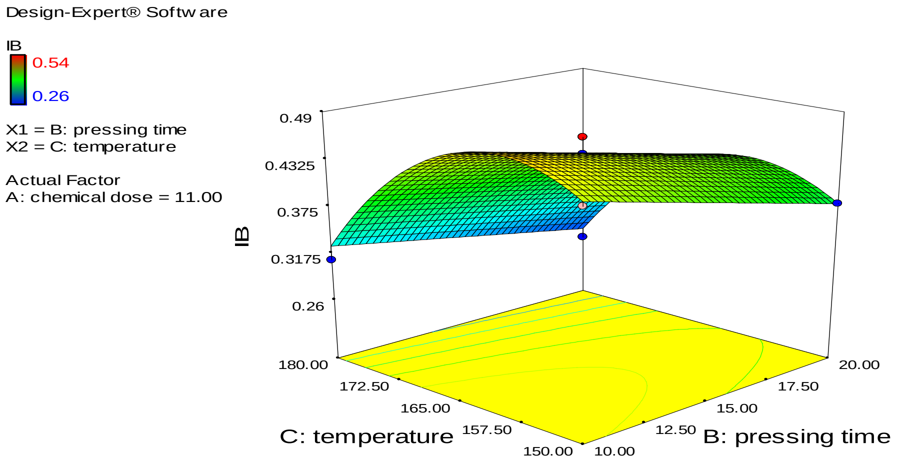

Figure 4-18 Surface plot of the inter action effect pressing time and pressing temperature versus internal bonding when the chemical adhesives was 11%

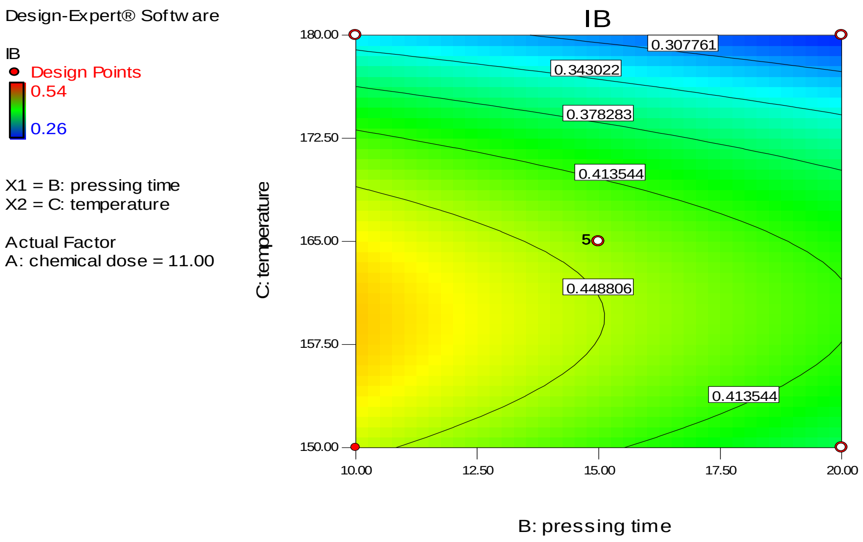

Figure 4-19 Contour plot of the inter action effect pressing time and pressing temperature versus internal bonding for chemical adhesives 11%.

Figure 4. 17 shows the interaction effect presing time and temprture to the internal bond shows reletivly lowr internal bonding at highr pressing time dueto the dgrade of cells of the stalk and dicomposition of the hemicelulose. On other hand figure 4.15 the interaction effect of chemical adhesive to presing temperature versus modules increases with incersing the resin adhecives at the intial temprture.

4.4 Optimization of process variables

The results shown that two proses variables and the interaction among the variables affects the quality of the board. Therefore, the next step is optimizing the proses variables in order to obtain the highest results of modules of rupture and internal bonding using the model regression developed. Form the design point of optimization the range maximum points selected as shown on the table 4.6 blow.

Table 4-6 Optimization of process parameters of cotton stalk particle board

No	Factor	In range	Lower	Upper
1	Adhesive	limits	8	14
2	temperature	limits	150	180
3	Time	limits	10	20
4	MOR		Maximum	
5	IB		maximum	

In order to obtain maximum strength and internal bonding, the predicted combination of parameters ware as follows, at 13.95% chemical adhesive and pressing time of 10.79 minute and pressing temperature of 150.69^{o}c the quality of the board will optimized to have modules of rupture 11.86 and internal bonding 0.56 MPa respectively, this indicates it was above experimental value, and good compering to the standard. There for this study shows that production of particle board from cotton stalk definitely use as alternative row material for board production which can be used for general purpose and internal fitments. Finally, using the above prediction points three experiment was conducted to validate the optimum prediction points of the particle boards and tested using universal testing machine the conducted result was almost close to the prediction points for both the modules of rupture and internal bonding. With manually reading experiments have average results 11.78 and 0.61 MPa for all.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Quality board can be produced from whole cotton stalks. Cotton stalks have potential end uses in manufacture of particle boards, hard boards, and corrugated boards. From this investigation the lignin, and cellulose in cotton stalks are comparable to same non-wood, and hard woods. The chemical composition, especially cellulose and lignin contents are near to the normal range so, it was possible to conclude it can serve as alternative raw material for particle board industries.

Cotton stalk has substantially higher hot and cold water solubility, alcohol-benzene extractive and hemicellulos than some softwoods and hard woods, which caused high water absorptions. This may have its own effects on the quality of the board.

The experimental produced board meets the mechanical properties of any standards, for general use in all standards for Bending strength and modules of elasticity and internal bonding. But not for the physical properties, for water absorption and thickness swelling, needs further investigations.

Irrespective to the water absorption and thickness swelling, generally it was possible to conclude for the production of cotton stalk particle board to use factors 10 minutes pressing time 150 ^{o}c pressing temperature and less than this factors.

From this study the production of particle board from cotton stalk definitely use as alternative row material for board production which can be used for general purpose and internal fitments. Exam pads, box, roofing,

5.2 Recommendations

In this research production of cotton stalk was done starting form morphological, compositional and some proximate analysis of the cotton stalk with three factors and three level. But further investigations are recommended to understand its behavior and to explore the commercial application of the cotton stalk particle board.

- Its microstructure and improving its physical properties and selection of resin adhesives with other factors like the particle size varying its operation density and pressing pressures with hot or cold presses.
- Water absorption and thickness swelling, which are two of the key qualities compared to commercial usage, has their limits much lower than the standard range and comparable to boards made from other proved materials by adding wax reducing, the particle geometry to

reduce the spring back effect not to destroy the adhesive line bonded well, And reduce the thickens swelling and water absorption also recommendable.

- There is the possibility of combining wood with other lignocellulosic materials aiming at obtaining more preferable products and with environmental marketing strategies, without reducing its quality. The fabrication procedure of this type of particleboard was standardized with those bonded with conventional resin to equivalently compare the physical, mechanical and morphological properties of the boards.
- It needs further investigations of reliability to use as alternative raw material for particle board producers in addition to, study of its availability, potentials and job creations using for other purposes is also important, and contribution on the environment, for the reduction of emission also would be useful.

Generally further study on improvement of the board quality process parameters pressing time, pressing temperature may improve its quality, especially using alternative resin and hardeners is also suggested.

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APENDICES

Appendix A: morphology of cotton stalk

Table A-1 Morphological data of the cotton stalk

Cell Well Thickness (Nm)	Lumen diameter (µm)	Fiber length (mm)	Fiber width (µm)
11.70	47.56	0.34	4.9
13.11	33.33	0.26	8.2
9.09	52.54	0.58	6.8
16.56	49.24	0.19	2.4
19.80	49.03	0.33	6.5
11.62	45.93	0.15	8.4
14.64	30.32	0.37	4.9
8.11	18.29	0.61	8.9
8.35	37.74	0.15	7.3
9.145	54.18	0.55	8.6
13.38	62.21	0.36	8.9
13.01	23.40	0.05	7.36
18.89	54.13	0.06	5.16
12.3	80.2	0.06	3.16
16.41	54.28	0.09	5.16
15.16	45.93	0.10	3.16
14.84	83.00	0.04	3.68
11.19	62.21	0.44	7.23
12.89	28.92	0.08	8.11
10.32	33.91	0.57	7.23
11.70	47.38	0.43	8.2
11.05	52.66	0.45	5.2
12.89	62.21	0.45	8.4
9.20	44.39	0.56	7.2
9.89	70.24	0.09	6.1
17.56	40.49	0.14	8.5

16.67	36.39	0.53	7.2
9.78	77.27	0.68	5.3
11.00	33.58	0.07	6.4
11.00	51.59	0.18	3.68
11.70	28.44	0.08	7.36
11.62	30.95	0.10	3.68
9.20	41.69	0.14	3.61
10.68	51.59	0.24	8.2
9.76	50.45	0.22	7.36
11.00	47.75	0.74	5.16
8.20	54.18	0.10	3.68
11.19	69.74	0.39	3.68
11.66	26.76	0.039	3.68
9.38	43.81	0.08	3.68
9.89	29.67	0.58	3.61
12.89	23.31	0.19	7.36
5.73	44.17	0.33	7.36
8.20	33.13	0.15	5.16
8.20	15.48	0.37	8.2
9.89	78.06	0.61	3.68
17.28	55.21	0.15	8.11
7.46	36.11	0.55	7.36
12.65	33.68	0.36	3.68
11.70	29.55	0.08	3.68
11.78	22.38	0.29	3.68
Ave. 11.8	**Ave 45.3**	**Ave 0.34**	**Ave 5.96**

Appendix B chemical composition of cotton stalk

Table B-1 cellulose determination of cotton stalk laboratory data sheet

No	Lab code	Sample code	Temperature ^oc	W sample in g	W crucible in g	W final in g	Wf-wc	Cellulose = $\frac{wf}{ws}$*100
1	1	C 1	110	1	34.783	35.177	0.395	39.5
	2	C 2	110	1	33.220	33.584	0.37	37.00
	3	C 3	110	1	32.935	33.343	0.4099	40.99
		Average						**39.32**

Table B-2 lignin determination of cotton stalk laboratory data sheet

Test No.	Lab code	Sample code	Temperature o_c	w_s in g	w_c in g	w_f in g	Wf-ws	Lignin= $\frac{wf}{ws}$*100
1	1	L 1	110	1	23.74	23.9801	0.2401	24.01
		L 2	110	1	35.916	36.1601	0.2441	24.41
		L 3	110	1	29.82	30.0723	0.2423	24.23
		average						**24.30**

Table B-3 hemicellulose determination of cotton stalk laboratory data sheet

Test No.	Sample code	^oc	w_s in g	w_c in g	w_f in g	W2 = (wf-wc)	H.C % = $\frac{w2}{w1}$*100
1	1	110	100	23.74	35.29	11.55	11.55
	2	110	100	35.916	46.216	11.03	11.03
	3	110	100	29.82	40.26	10.54	10.54
	average						**11.07**

Table B-4 Cold water extractive of cotton stalk laboratory data sheet

No	Weight of sample (Ws) in (g)	Weight of crucible (Wc) in (g)	(Wc)+ (Ws final) in (g)	$Cw\ (\%) = \frac{w1-w2}{w1}$*100	% extractive
1	2	35.307	37.089	1.762	11.90
2	2	34.639	36.397	1.758	12.10
3	2	34.642	36.411	1.769	11.55
		average			**11.85**

W_1= is final result by subtracting ((wc + ws)-(wc))-(ws) and w_2 = weight of sample

Table B-5 **Hot water extractive of cotton stalk laboratory data sheet**

No	Weight of sample (Ws) in g	Weight of crucible (wc) in (g)	(Wc)+ (Ws) in (g)	$Hw\ (\%) = \frac{w1-w2}{w1}*100$	% extractive
1	2	34.642	36.451	1.809	9.55
2	2	35.310	37.115	1.805	9.75
3	2	35.312	37.119	1.807	9.65
		average			**9.68**

W1= is final result by subtracting ((wc + ws)-(wc))-(ws) and w2 was w2 = weight of sample

Table B-6 Alcohol Benzene extractive of cotton stalk laboratory data sheet

No	Weight of sample (Ws) in (g)	Weight of flask (Wf) in (g)	(Wf)+ (Ws) in (g)	$A.B\ (\%) = \frac{w2}{w1} * 100$	% extractive
1	2	193.734	193.812	0.078	3.90
2	2	139.093	139.169	0.076	3.80
3	2	139.264	139.334	0.07	3.50
		Average			**3.74**

Appendix C proximate analysis of cotton stalk

Table C-1 moisture content determination of the stalk

Test No.	Sample code	°c	W_s in (g)	W_c in (g)	W_f in (g)	W_c in (g) - W_f in (g)	MC (%)	Average Mc (%)
1	1	105	2	36.3	38.1	1.8	10	**4.13**
	2	105	2	38.7	40.5	1.8	10	
	3	105	2	35.6	37.41	1.81	9.5	
2				36.3	38.2	1.9	5.0	
				38.7	40.6	1.9	5.0	
				35.6	37.5	1.9	5.0	
3				36.3	38.23	1.93	3.5	
				38.7	40.61	1.91	4.5	
4				35.6	37.512	1.912	4.4	
				36.3	38.23	1.93	3.5	
5				38.7	40.61	1.91	4.5	
				35.6	37.512	1.912	4.4	
				36.3	38.23	1.93	3.5	
6				38.7	40.61	1.91	4.5	
				35.6	37.512	1.912	4.4	
				36.3	38.23	1.93	3.5	
7				38.7	40.61	1.91	4.5	
				35.6	37.512	1.912	4.4	
				35.6	37.512	1.93	3.4	

ws = weight of sample, wc = weight of crucible, wf oven dry sample with crucible , MC = moisture content, oc = temperature

Table C-2 Ash content determination of cotton stalk laboratory data sheet

test No	Lab code	Sample code	Temperature	W $_{sample}$ in(g)	W $_{crucible}$ in (g)	W $_{final}$ in (g)	$Ac\ (\%) = wf/ws * 100$
1	1	A 1	650	2	41.757	41.814	2.85
	2	A 2	650	2	42.275	42.330	2.75
	3	A 3	650	2	40.0085	40.066	2.875
		Average					**2.825**

Appendix D Testing the Particle Board

Table D- 1 Laboratory data sheet for moisture contest test of the board

No of Run	Sample code	Sample No	Mass air dry (g)	Mass of oven dray (g)	Deferens (g)	MC (%)	Average
1	11/10/180º	1	14.58	13.54	1.04	7.13	
		2	16.0	14.90	1.1	6.9	7
		3	16.85	15.69	1.16	6.9	
2	11/10/165	1	17.01	14.96	2.05	6.93	
		2	17.6	15.38	1.22	6.93	7.1
		3	17.83	16.14	1.69	7.3	
3	11/10/150	1	16.69	15.29	1.4	8.3	
		2	17.01	15.62	1.39	8.1	8.1
		3	16.44	15.09	1.35	8.2	
4	11/ 15/165	1	16.64	16.19	.95	7.7	
		2	15.3	14.2	1.28	8.4	7.96
		3	15.3	14.4	1.02	7.9	
5	11/20/150	1	16.92	15.53	1.39	7.82	
		2	16.78	15.41	1.37	7.71	7.78
		3	18.11	16.62	1.49	7.92	
6	11/20/165	1	16.81	15.54	1.27	7.8	
		2	16.63	15.39	1.24	7.5	7.6
		3	16.42	15.19	1.23	7.5	
7	14/15/150	1	16.77	15.68	1.09	6.5	
		2	15.87	14.76	1.11	6.99	6.7
		3	17.35	16.20	1.15	6.63	
8	14/20/165	1	18.10	16.91	1.19	6.57	
		2	16.30	15.23	1.07	6.56	6.53
		3	17.13	16.01	1.12	6.54	
9	8/ 20/165	1	14.67	13.77	0.9	6.1	
		2	16.91	15.81	1.1	6.51	6.45

		3	17.52	16.34	1.17	6.73	
10	14/10/165	1	14.52	13.4	1.12	7.71	
		2	15.53	14.334	1.19	7.66	7.5
		3	16.71	15.51	1.2	7.18	
11	14/15/180	1	16.77	15.68	1.09	6.5	
		2	15.87	14.76	1.1	6.8	6.64
		3	17.35	16.20	1.15	6.63	
12	8/15/180	1	16.42	15.23	1.19	7.24	
		2	15.85	14.73	1.12	7.06	6.9
		3	15.32	14.30	1.02	6.65	
13	8/ 10/165	1	14.51	13.39	1.12	7.72	
		2	12.53	11.52	1.01	7.71	7.72
		3	14.32	13.17	1.15	7.73	
14	11/15/165	1	14.2	13.14	1.06	7.6	
		2	14.28	13.2	1.08	7.6	7.5
		3	14.85	13.75	1.11	7.4	
15	11/15/165	1	16.95	15.04	1.31	7.73	
		2	15.56	14.33	1.23	7.9	7.82
		3	17.09	15.75	1.34	7.84	
16	8/15/150	1	15.19	14.01	.94	6.0	
		2	14.15	13.33	0.85	6.0	6.0
		3	15.14	13.81	1.33	6.0	
17	11/ 20/180	1	13.75	12.78	0.97	7.85	
		2	13.79	12.84	0.95	6.8	7.12
		3	14.19	13.19	1.00	6.7	

Table D - 3 Average results (WA) and (TS) particle board cotton stalk

sample cod	Average (TS) @ 2 hrs (%)	Average (TS)% @ 24 hrs %	Ave (WA) @ 2 hrs %	Ave (WA) @ 24 hrs (%)
14/15/180	61.29	64.57	105.87	109.06
14/15/150	60.72	63.67	102.38	107.01
14/10/165	65.07	69.86	102.42	102.60
14/20/165	53.47	65.10	112.56	113.66
8/15/180	61.38	71.32	116.66	127.74
8/10/165	85.96	88.05	138.49	142.65
8/20/165	86.15	91.54	123.24	131.82
8/15/150	66.19	85.45	127.55	138.75
11/10/150	57.30	66.30	117.88	145.14
11/15/165	80.21	81.03	116.36	128.40
11/15/165	60.66	67.21	112.68	124.21
11/20/150	62.59	86.47	112.80	127.86
11/15/165	73.13	82.57	106.49	116.49
11/20/180	72.83	81.31	106.96	109.96
11/15/165	74.37	74.37	118.47	118.47
11/15/165	72.01	80.75	128.38	139.96
11/10/180	60.97	63.12	121.03	124.15

Appendix E print out Figure for MOR and MOR Respectively

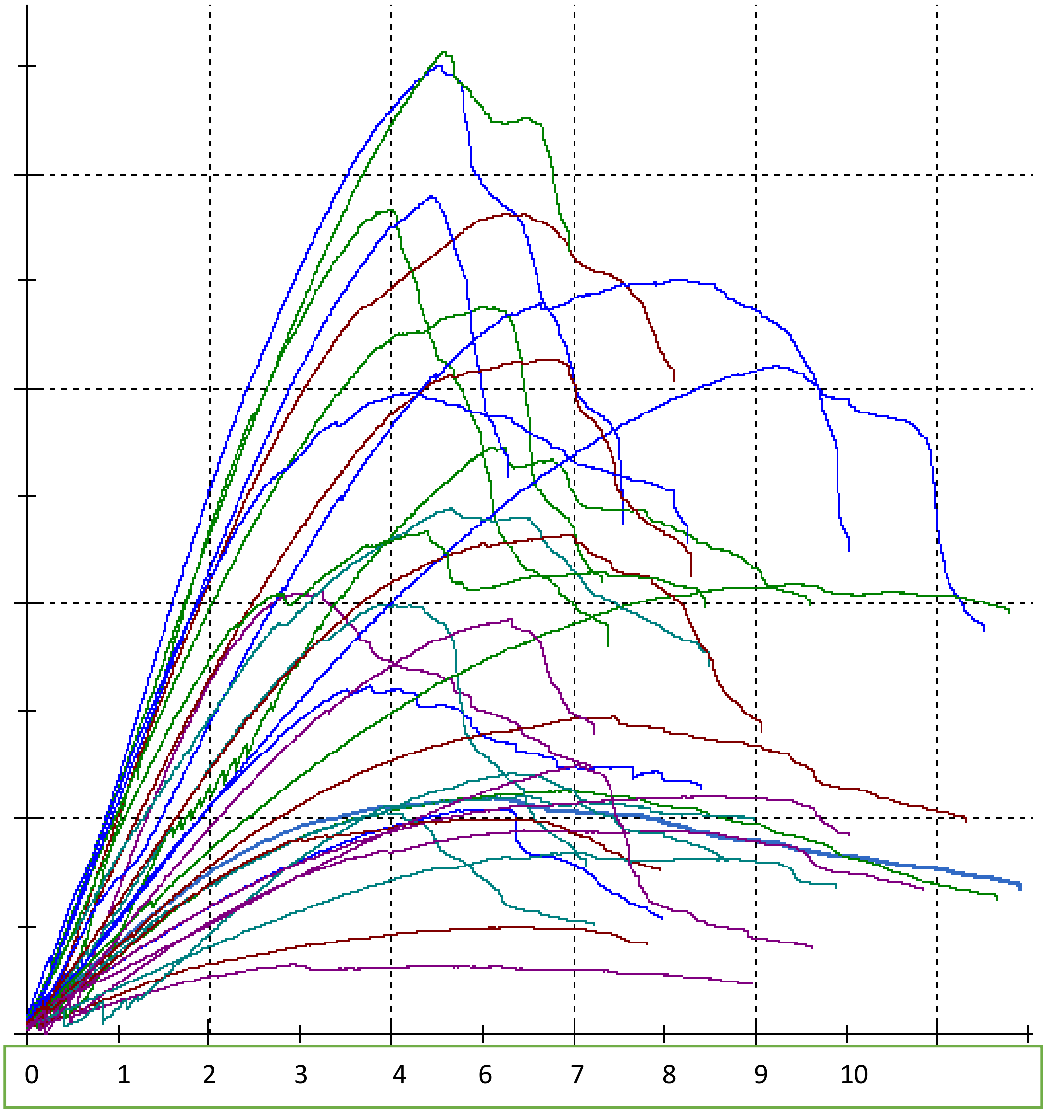
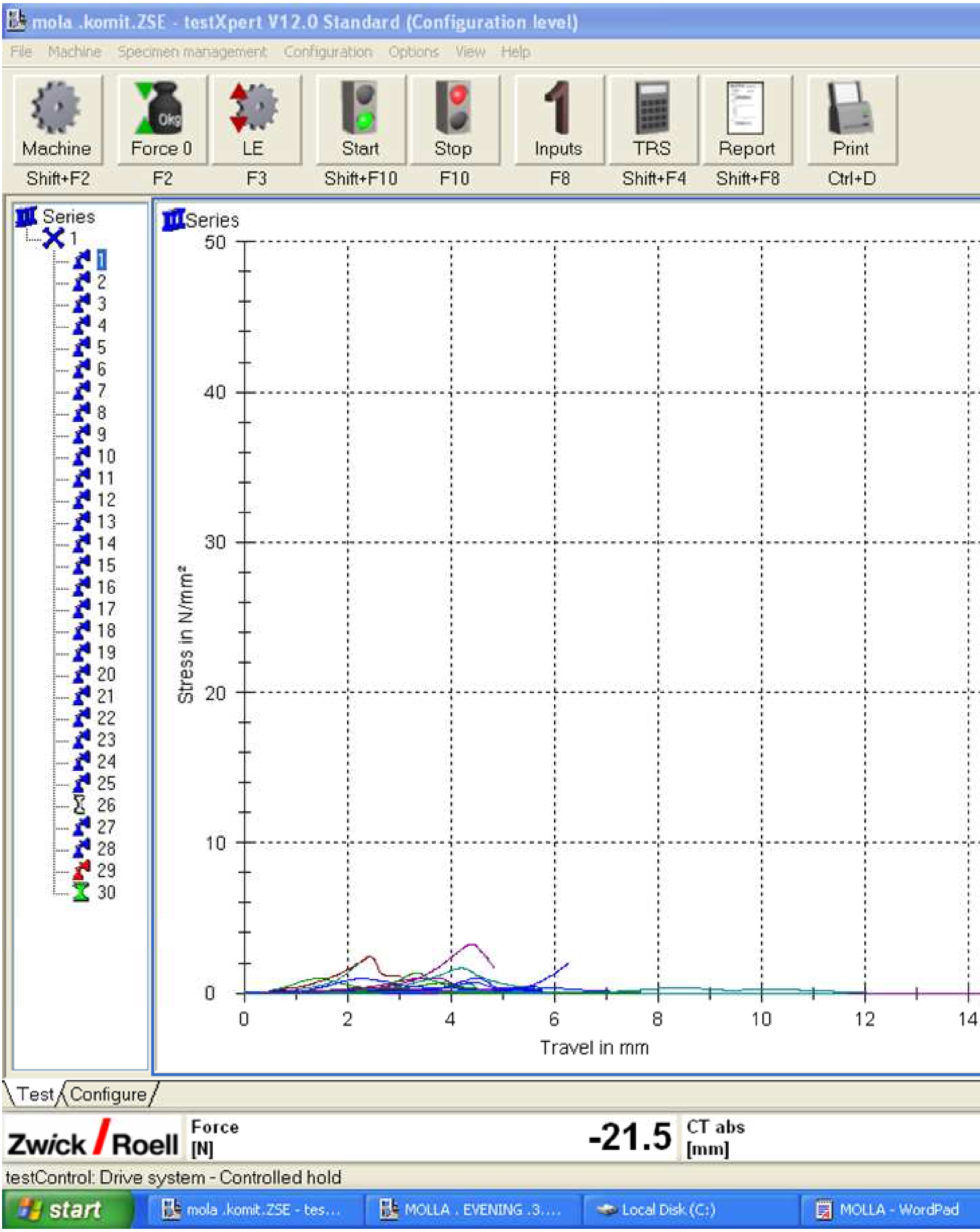


Figure E-1 photos of flexural test for particle board of cotton stalk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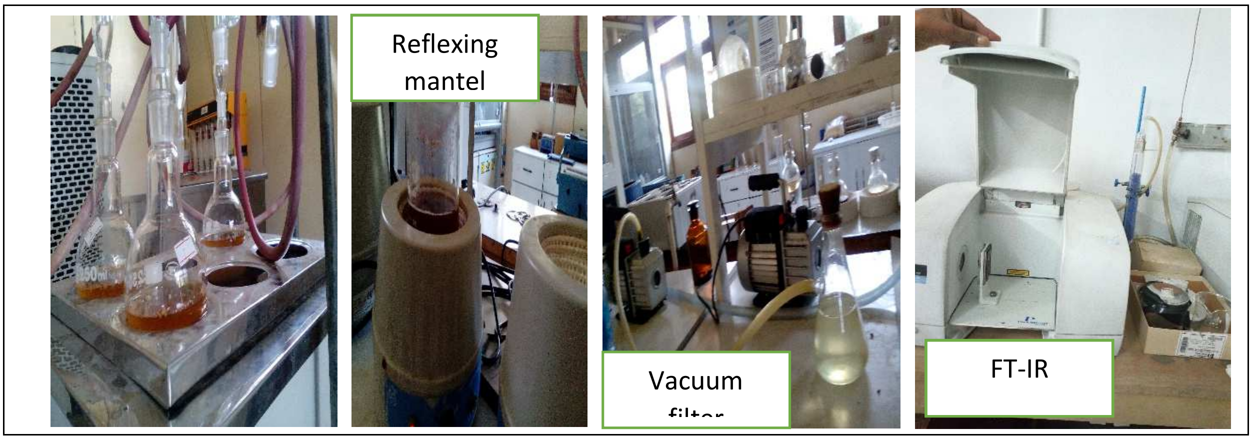
Appendix **F same photos of experiments**

Photos of size reduction and morphology determination equipment's



FT-IR and copositional analysis equipments

Some particle bord porduction equipments

Same stapes of experimental work and products

Some laboratory testing equipment phots of the board