ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAiT)

School of Chemical and Bioengineering

Development and Characterization of Particle Board from Maize Cob by Using Polyvinyl Acetate Adhesive

By

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A thesis submitted to the School of Chemical and Bio engineering as part of the partial fulfillment of the requirement for the degree of Master of Science (chemical and Bio engineering in the process engineering stream)

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DECLARATION

I declare this thesis entitled ‘’**developmen**t **and Characterization of Particle Board from Maize Cob by Using Polyvinyl Acetate Adhesive**" for an M.Sc. degree at Addis Ababa University, here submitted by me, to be my original work and has not been submitted for any degree, diploma, or award at any university or institution. A list of references is provided, and information and citations from other people's published works have been properly recognized in the text. Addis Ababa University lecturer Prof. Belay Woldeyes provided direction for this effort.

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This is to certify that the above declaration is corrected to the best of my knowledge and with the approval of my university advisor.

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ABSTRACT

Waste management and recycling have led to numerous studies on particleboard production. The problems we face globally are clear responses to human resource mismanagement, including global warming, sea-level rise, floods, and earthquakes. This study attempted to use milled corncob and polyvinyl acetate to produce particleboard. This research was aimed to produce a particleboard from corncob with the addition of polyvinyl acetate resin as an adhesive. Further, characterization of the developed particleboard has been conducted against to some selected quality attributes of the product, including density, water absorption, thickness, moisture content, and flexural strength. Furthermore, some control variables (temperature, pressure and polyvinyl acetate) were considered for their effects on the quality of the outlined particleboard. The decline of the world's forest reserves, rising prices of wood products, and environmental concerns about particleboard have led governments and scientists to explore alternative renewable energy sources, feasibility, market competition, and environmental acceptance. To achieve the outlined study, a total of 27 experimental trials were generated from different formulations of the selected process parameters using a general factorial design. The formulations of maize cob particle to polyvinyl acetate were defined at 70:30, 65:35, and 60:40. These formulations were poured into a mold with dimensions of 100mm x 100mm x 15mm. Findings of this study showed that as *the polyvinyl acetate content increased from 30-40g, the hardness of maize cob increased* from710 to2930N.*The board densities varied between 407.384 and 642.944 kg/m*^{3}*. With increasing immersion time, the percentage of water absorption increased from 37.44 to 100.*The *It was discovered that all boards had an average moisture content of 68.72%. The* mean *bending stress (flexural strength) was* 3.7605*Mpa, a relatively low bending strength compared with urea but higher strength than starch resin-made particle board. Also, the thickness of the particleboard ranges between 6.325 and 9.325mm. In conclusion, the results of this study showed that the particleboard prepared from the combination of maize cob and polyvinyl acetate would be used as an alternative for ceiling roofs, building and furniture applications. The outcome of this study may serve as a guideline for any manufacturer who intends to use corn cob as supplement for production of particleboards.*

Keywords*:* Particle Board; Maize Cobs; Polyvinyl Acetate; Flexural Strength

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List of abbreviations

AC..Ash content
c...Weight of oven dry sample
CC..Corn- cobs
EPS..Expanded polystyrene
GFD...General Factorial Design
HCF...Hawassa Chipwood Factory
Mc..Moisture content
MC...Maize cobs
MOE..Modulus of elasticity
MOR..Modulus of rupture
PF...Phenol Formaldehyde
PVA...Polyvinyl acetate
RH...Rice Husk
RL...Resin Load
Th...Thickness
UR...Urea Formaldehyde
w..Width
WA...Water Absorption
Wa...Air-dried weight
Wcr..Weight of Crucible
EPS..Extruded Polystyrene

1. INTRODUCTION

1.1. Background of the Study

The continuous increase in the global human population has led to a corresponding increase in the scarcity of basic survival needs of people. This scarcity raises concerns about the ability of future generations to meet their own needs in years to come. The problems we face globally are clear responses to human resource mismanagement, including global warming, sea-level rise, floods, and earthquakes. The solution to these problems is the principle of sustainable development, which involves reducing waste generation and recycling waste in a way that supports economic, social, and environmental goals. Agro waste, such as grape vines, fruit-bearing trees, sugarcane, bagasse, and corncob, is a significant source of solid waste. This study examines the possibility of converting agro waste, particularly corn cob, into particle boards Kumar, A. *et al.*, (2020).

Among the already mentioned residues, maize cob is worthy of special mention due to its high volume productivity, with corn (Zea mays L.) being ranked third among the most widely cultivated cereals worldwide, after wheat and rice (FAO, 2008). The potential of raw materials made from agricultural leftovers to replace wood in different particleboard industrial applications has drawn more and more attention in recent years. There are multiple reasons for this development, particularly in nations where wood is less readily available than other cellulosic materials. Traditionally, wood-based materials have been used in the production of composite panels. Particleboard production has increased throughout time, and this has resulted in a change and expansion of the raw material mix. Although industrial wood harvested from forests constituted the majority of the resource at first, over the course of the last fifty years, the proportion of industrial waste wood has risen, reaching 54% in 2005 (Abetie, 2021).

In actuality, over the past few years, there has been a tendency for the amount of maize produced to increase. Utilizing this agricultural waste could lead to the production of a sustainable and alternative product that could be useful given the annual global production of corncob. Like many other agricultural fiber sources, corn stalks have an outer layer of long fibers and a pithy interior. Through improved productivity in manufacturing procedures, R&D, and other areas, light wood products could eventually be produced at a lower cost while maintaining a higher level of quality. In the furniture industry, this trend is extremely strong. (Gadea, 2010 (spain)).

The use of polyvinyl acetate for the production of particleboard and as an adhesive resin has been reported due to its high reactivity, good performance, and low price. The use of polyvinyl acetate for the production of particleboard using sawdust has also been reported. Maize cob is obtained after removing the maize seeds from the cob. The corncob is made up of cellulose and lignin. One of the most important characteristics of corncob products is their absorbency their capacity to hold up to four times their weight in fluid. This absorptive quality enables corncob products to be used to absorb finishing fluids, oil and water in industrial applications and to clean up industrial or environmental spills. The abrasive quality of corncob particles makes them valued for their use as industrial abrasives (Bode Haryanto, 2023).

Corncobs, along with other biomass resources, have the potential to be transformed into valuable bio-products for industrial and consumer use. This transformation is driven by environmental concerns and the desire to reduce the use of imported oil, which has led to significant technological advancements in converting corn and its components into various products. This research aims to produce particle boards from maize cob using polyvinyl acetate (PVA) as a binder, while also studying the properties of these boards to add value to maize cob and reduce demand. Many particle boards are currently manufactured from wood chips and expensive binders like phenol formaldehyde, urea formaldehyde, and isocyanate epoxy. These binders are not only expensive but also not easily available locally, which has significant environmental impacts. For instance, urea formaldehyde, a commonly used binder, is expensive and toxic to the ecosystem. Due to these concerns, this study aims to replace urea formaldehyde with PVA, which is economically cheap and environmentally friendly (Danladi, I. O. (2013).

Maloney (1977) highlights the importance of using PVA as a binder due to its high reactivity, good performance, and low price. This shift towards using PVA as a binder can significantly reduce the environmental impact of particle board production. Overall, this research aims to contribute to the development of sustainable and environmentally friendly particle boards by utilizing maize cob and PVA as a binder, thereby reducing the demand for expensive and toxic binders like urea formaldehyde. All binders are expensive and not easily available locally. This declaration has many effects on the environment. I know that many industries use urea formaldehyde, which is expensive and toxic to the ecosystem.

1.2. Problem Statements

Particle board is produced from log it increases the deforestation. The release of some unnecessary pollutants also contributes to the depletion of the ozone layer in the atmosphere. The decline of the world's forest reserves, rising prices of wood products, and environmental concerns about particleboard have led governments and scientists to explore alternative renewable energy sources, feasibility, market competition, and environmental acceptance. Zhang, Y. *et al.*, (2018).

Among other renewable energy sources, corn derived from biomass has recently received more attention as it has replaced wood. Most particleboards in my country are made using wood sawdust. This can lead to deforestation, damaging the environment. According to research data, maize cob is not used commercially in the production of lignocellulosic particleboard. Industrialization and urbanization are constantly increasing in our country, Ethiopia. The construction industry, where wood and wood products are used, is growing rapidly in developing countries. Remaining crop materials are materials produced in many parts of the world and can accumulate to a level that causes environmental problems. Especially carbon monoxide, because nature relies on plants to reduce carbon dioxide in the air, which will decrease when they are not around for the same reason humans play and need wood.(Abetie, 2021).

Corn production is expected to increase every year depending on global demand. Depending on the end use of wood waste and recycled materials, applications of particleboard include floors, walls and ceilings, offices, newspapers, furniture seats, shelving, kitchen countertops and tabletops, and particleboards derived from biomass waste have been found to be good candidates for recycling. Although most agricultural panels are environmentally friendly, sometimes their materials are poor and their water resistance limits their work Dien, B. S. *et al.*, (2006).

1.3. Objectives

1.3.1. General Objective

The general objective of this study is to produce an alternative particleboard from corn cob and polyvinyl acetate (PVA), which is used as an adhesive, and to characterize the developed product against some selected quality attributes.

1.3.2. Specific Objectives

1. To recognize and describe the basic materials and additives used in the production of particleboards, including the corn cob and PVA.
2. To investigate the mechanical properties of particleboards produced from corn cob and PVA.
3. To optimize the physical properties of particleboards, such as density, moisture content, and dimensional stability.
4. To investigate the processes involved in the production of particleboards, including the preparation of corn cob particles and the mixing of particles with PVA.

1.4. Research Questions

Based on the specific objectives provided, here are the corresponding research questions:

1. What are the characteristics of the raw materials and additives used in the production of particleboards, specifically corn cob and polyvinyl acetate (PVA)?
2. How do the mechanical properties of particleboards produced from corn cob and PVA compare to those made from traditional wood sources?
3. What methods can be employed to optimize the physical properties of particleboards, including density, moisture content, and dimensional stability?
4. What are the specific processes involved in the production of particleboards, particularly in the preparation of corn cob particles and the mixing process with PVA?
5. Does corn cob suitable for development of the particleboard?

1.5. Scope of the work

The scope of the work for this study includes: Collection of corn cob from various sources in Ethiopia, drying and grinding the corn cob into fine particles and sieving the particles to achieve a uniform size distribution. Mixing the corn cob particles with polyvinyl acetate (PVA) adhesive, forming the mixture into a mat using a mechanical unit operation, hot pressing the mat under controlled temperature and pressure to create a particleboard, cooling and finishing the particleboard to achieve the desired thickness and surface quality.

Determining the density, moisture content, and dimensional stability of the particleboards, measuring the flexural strength, impact resistance, and other relevant properties of the particleboards. Investigating the effects of temperature, pressure, and PVA content on the physical and mechanical properties of the particleboards, identifying the optimal conditions for producing particleboards with acceptable mechanical properties. contrasting the mechanical and physical characteristics of particleboards made from corn cobs with those made from more conventional materials, such as wood. This comprehensive scope ensures that the study covers all aspects of producing particleboards from corn cob and PVA adhesive, including raw material collection and preparation, particleboard production, and physical and mechanical properties analysis.

1.6. Significance of the Study

The significance of this study on producing particle boards from corn cob and polyvinyl acetate (PVA) adhesive is as follows: The study demonstrates the feasibility of converting corn cob, an agricultural waste material, into value-added products like particle boards. This approach aligns with the principles of sustainable development by reducing waste and creating useful products from agricultural residues. The use of corn cob and PVA adhesive for particle board production is more environmentally friendly compared to traditional methods that rely on wood and synthetic adhesives. Cutting down trees and using synthetic adhesives can have negative impacts on soil, water, climate, and ecosystems, such as loss of biodiversity, climate change, loss of soil fertility, flooding, water pollution, and formaldehyde emission.

The successful production of particle boards with acceptable mechanical properties from corn cob and PVA adhesive opens up opportunities for commercialization and industrial-scale production. This could lead to the development of new industries and create employment opportunities. The findings can serve as a reference for future research and development in this field. Particle boards derived from corn cob and PVA adhesive can be used as an alternative to wooden products, addressing the disadvantages associated with the use of wooden products, such as deforestation, scarcity, and high costs. In summary, this study on producing particle boards from corn cob and PVA adhesive has significant implications for sustainable waste management, environmental protection, and the development of alternative building materials.

2. LITERATURE REVIEW

2.1. Particle Board Production from Organic Waste

Compared to rice residues, corn residues have been the subject of less investigation in the particleboard industry. However, there are a number of explanations for this phenomenon. First off, maize wastes are already put to good use for a variety of purposes.

You can shred the entire plant and feed it to the animals. Granulated CC residues have good water-absorbing qualities and can be used as mulches, soil conditioners, bedding for poultry, mushroom-growing compost ingredients, and filler in industrial applications.

There is a tremendous deal of variation in the information given by various sources regarding the chemical makeup of CC. The high water absorption capacity of CC, which amounts to 69% dry solids, makes it a promising material for the application of water-based adhesives (Watson, 1987).

After creating particleboard using various combinations of bagasse, CC, and wood shavings bound with urea formaldehyde glue and tannin resorcinol, respectively, and conducting dry and wet bending tests, they discovered that the majority of their panels outperformed wood-based panels of commercial grade. There was no treatment applied to any of the materials to improve adhesion qualities before bonding, and the percentage of CC in the mixtures varied from 25 to 50% by weight.

The Cortical Layer: This is the exterior layer of the cob, made up of both fine and coarse chaff, on which the corn grains are organized. It has a yellowish hue and works well to create fibers.

The Wood Blast: This is the cob's principal component. Encircling a core of pith is a strong, resistant coating of wood. Its proportion grows from top to bottom, making it useful for creating boards.

The pith: This is the core of the cob, made up mostly of soft tissues. The grinding procedure readily turns it into a powder.

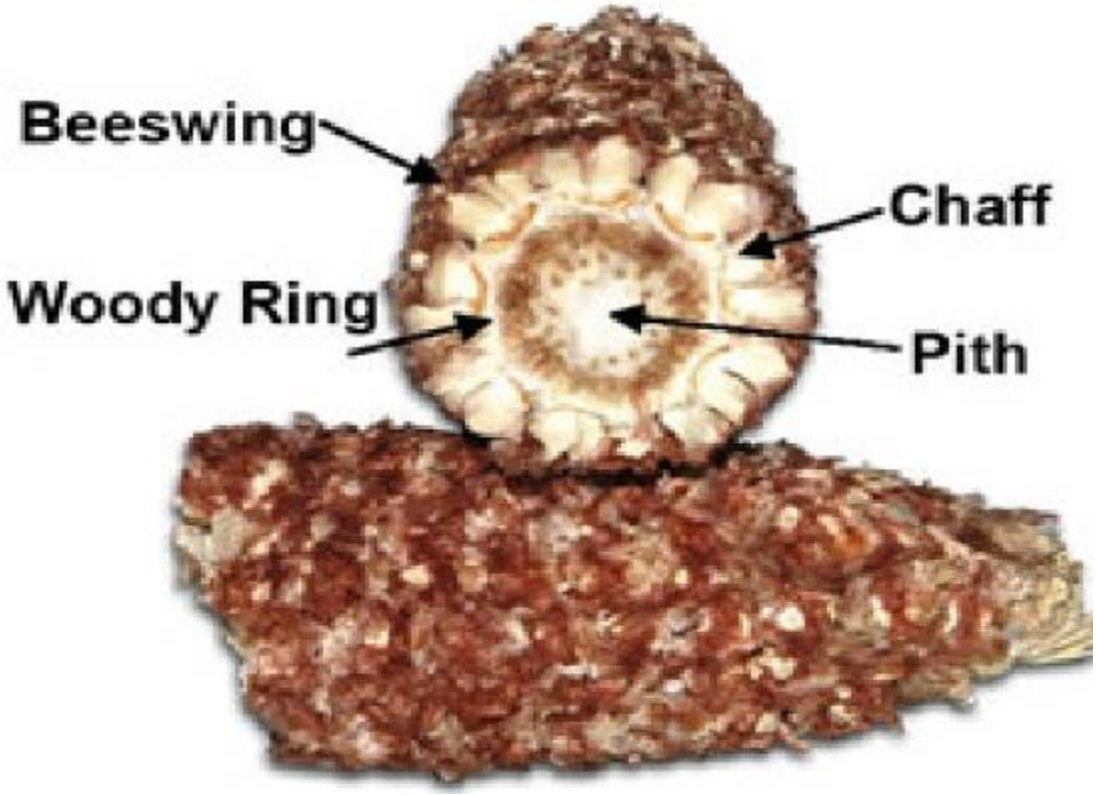

Figure 2.1: Structure of maize cob

2.2. Properties of Maize or Corn Cob

It has relatively homogeneous properties, making it an excellent core material for furniture manufacturing. Over the years, the industry has concentrated its efforts on improving board surface smoothness for improved finishing and laminating purposes.

2.3. Purpose of corncob in Production of board

It is crucial that the raw materials utilized in the manufacturing of particle boards be suitable; in fact, one of the goals of this thesis is to achieve just that. Therefore, it is essential to understand the physical and chemical properties of the raw material. This will help determine its composition and the degree to which it can be used for the desired purpose.

2.4. Board

According to Zubairu (1989), it is vital to examine the features of its related products in order to facilitate the evaluation of the prosperity. Veneer, which are thin sheets of wood, are used to make plywood. The grain of the center veneers is aligned with the outer sheets' grain when the sheets are bonded together under pressure.

Plywood can be purchased commercially in thicknesses between 3 and 25 mm, however for some applications, this range can be expanded (Leigh, 1980). Conversely, fiber construction boards are composed of wood fibers, also known as wood pulp. Wood fibers are self-adhesive, hence most fiber boards are created without the need for extra bonding agents.. Plywood is lighter than hardboard, unless lightness is required. It has several benefits, including affordability and simplicity of application for surface finishes; furniture making and building construction both employ it (Zubairu, 1989).

2.4.1. Origin and Development of Particle Board Plants

According to a 1958 report published by the UN Food and Agriculture Organization (FAO), some experimental work on the manufacturing of particle boards was done in North America and Europe prior to 1940. Nevertheless, the extrusion method was established by 1949, and the first commercial facility began operations in 1941 in Germany. The potential for employing some agricultural leftovers had been investigated between 1940 and 1946.

2.4.2. Classification of Particle Boards

Based on density, particle boards are often divided into three basic classes or categories by international usage, according to Zubairu (1989). Particle board is typically utilized in the furniture and construction industries. Particle board is utilized in the construction industry for ceiling linings, roof decking, dry wall partitioning, and flooring—either on solid floors or on joists. particle board classification based on density: low particle board density between 300-400kg/m^3, medium (400-800kg/m^3) and high density (particle board density above 800kg/m^3).

2.5. Production of Particleboards Using the Traditional Method

Particleboard panels are made by pressing wood particles—like wood chips, maize cobs, and rice husks—together with the right binders under either heated or cold conditions. Because maize cobs are naturally fibrous, processing them into boards requires little energy. (Bhatnagar, 1994).

2.6. Production of Particleboards Using the Classical Method

Including paper and hard boards, a traditional method of producing rice husk ceiling boards exists. The manufacturing of far less expensive ceiling planks is made possible by the use of maize cobs. Sawdust and corn are combined to make it. By boiling corn cobs with caustic soda, slurry is created. After this slurry has been cleaned with water and beaten into pulp, glue and sawdust are added. The slurry was pressed into sheets and allowed to dry in the sun. (Ajiwe, 1998).

2.7. Main things in the manufacturing of board

The trays are put in hot presses and forced to press at a precisely calibrated pressure of 1.4–2.4 N/mm2 for approximately 15 minutes at 1000–1400 °C. Particles are continually dispersed on a moving belt in the continuous press process, which goes through a preheater and an electrically heated press. Materials, both wood and non-wood, must adhere to the following criteria must be met by realistic board manufacturers: they must be affordable, readily available in sufficient quantities, ideal farms for the production of boards, and requiring relatively little handling and storage expenses.

2.8. The Role of Adhesives

A substance known as an adhesive is used to connect or attach particles together. Adhesives can be made from synthetic or natural materials. Certain adhesives create incredibly strong connections, which are more and more crucial in today's building sector.

When creating composite items made of wood, adhesives are a necessary and common component. The cure timetables for adhesive-type materials differ based on the type of composite being used. Additionally, the glue needs to have enough flow to improve particle coverage while withstanding the rigors of particleboard manufacture. However, excessive flow will cause glue droplets to be displaced from the glue line into the interstices, resulting in particleboards with subpar qualities (Ndazi B. K., 2007).

2.8.1. Natural Adhesives

Before petroleum resins were introduced in the early 1930s, adhesives were made from agricultural resources in the early 1900s. The word "biodegradable" has become widely used in recent years to refer to ecologically friendly items. When it comes to plastics, it refers to any plastic that may be broken down by microorganisms like fungi, bacteria, and algae.

2.8.2. Synthetic Adhesives

Commonly used synthetic adhesives in the manufacture of particleboards are phenol formaldehyde, urea formaldehyde, isocyanate epoxy, and polyvinyl acetate resin adhesive.

2.8.2.1. Phenol Formaldehyde (PF)

Although PF resin demands the longest press periods and highest temperatures, it forms strong, water-resistant connections. Because of its intrinsic darkness, cured PF is not recommended for use in decorative products like paneling and furniture. RH particleboards using PF as the binder have modules of elasticity (MOE) and modulus of rupture (MOR) of 2.6 GPa and 13 MPa, respectively (Leiva et al., 2007). According to Ndazi B. K. (2007), the ground maize cob has a modulus of rupture of 7 MPa and an elastic modulus of 1.6 GPa. Web is impregnated with phenol formaldehyde, a thermosetting resin, to create web goods that are resistant to heat and water. The technique used for applying the resin is comparable to the dip-and-scrape method. Excess resin is eliminated from the paper by running it through pinch rollers, which regulates the amount of resin in the paper. The impregnated paper is heated in order to polymerize the resin.

2.8.2.2. Formaldehyde with Urea (UF)

Relatively high molecular weight polymers of formaldehyde and urea distributed in an aqueous media are known as urea-formaldehyde resins (Maloney, 1977). They were created at the start of the 1930s. For the past few decades, urea formaldehyde resins have been the best glue utilized in the production of particleboard due to a number of advancements in technology and a decrease in cost (Moslemi, 1974).Usually, condensation in aqueous, basic media is used to create them.

Both urea and phenolic resins have reduced viscosities at higher room temperatures. For the manufacturing of particleboard, it is generally advised that the resin viscosity vary between 0 and 500 centipoises at 210 °C. A specific proportion of solids are present in an aqueous medium in the urea and phenolic formaldehyde resins. However, an extremely high solid content may cause the resin to become too viscous, which will lead to issues related to the previously described viscosity of the resin (Moslemi, 1974). When great water resistance is not needed but surface smoothness is, UF resin is utilized because it is cheap. Ciannamea, Leiva P. (2007).

2.8.3. Effect of Resin Content

Research has shown that increasing the resin content of particleboard can significantly improve its strength and dimensional stability. According to calculations, the influence of particle geometry on MOR values was significantly greater than that of adhesive content (UF). These resins are a thermosetting adhesive, which means they cannot be reversed to their original form after curing. Urea and melamine (amino resins) are polymeric products of the aldehyde reaction with compounds carrying $–NH_2$ or -NH groups.

Urea and urea formaldehyde are products of the condensation reaction between urea and formaldehyde in the presence of an alkaline catalyst.

Advantages of UF

- Low cost
- Low-temperature curing
- Resistance to microorganisms
- Hardness
- Excellent thermal properties
- Lack of color
- Long storage time.

Disadvantages of UF

- Low moisture resistance
- High formaldehyde emissions
- Not resistant to weathering

Phenol formaldehyde is the product of the condensation reaction between phenol and formaldehyde. There are two main types of PF resins, which are called the resoles and the novellas. The differences between them are their molar ratio, the type and amount of catalyst used, and the temperature of the reaction.

Advantages of PF

- Are durable and exhibit resistance to breakdown both in cold and hot water. water.
- Resistance to common organic solvents
- Good resistance to high temperatures
- Tolerant to fungicides, water repellants, and fire retardants

Disadvantage PF

- Impact color on the resulting board
- Have high energy.
- Lower line speeds (productivity)

Melamine formaldehyde is the product of the condensation reaction between melamine and formaldehyde.

Advantages of MF

- MF adhesives possess better water resistance and bonding properties than UF adhesives.
- MF cannot be cured at room temperature.
- The adhesive can be heat-cured without any catalyst.

The only disadvantage of melamine formaldehyde is that it is more expensive than urea formaldehyde and phenol formaldehyde. Melamine formaldehyde adhesive is used only in wood products that require more durability and water resistance and in special products that require colorless pulling. MF resins are also used as laminating resins, surface coating resins, paper treatment resins, and textile treatment resins.

2.8.4. Isocyanate Epoxy

Epoxy is a type of polymer with an incredibly high tensile strength, ranging from at least 5,000 PSL toward 10,000 PSL.

Most epoxy resins come in two parts and must be mixed to activate. Epoxy is waterproof, waterproof, and cure times vary greatly. Woodworking-specific epoxies, such as JB WoodweldEpoxy, are set in 6 minutes and cure in one to three hours. Other epoxies can take days to cure. Epoxies are most commonly used in woodworking to fill in cracks and voids. These wood glue properties can come in handy when you have a misaligned joint. Just mix sawdust, epoxy together, and rub them into any gaps. While you can do the same with other wood glues, epoxies take a finish better and blend well into the finished wood. The downside to epoxies is that they are expensive. They also don't work well with acidic woods or when a wood block has residual moisture.

2.8.4.1. Polyvinyl Acetate

Polyvinyl acetate is commonly known as wood glue, PVA glue, white glue, and carpenter's glue. Is an adhesive used to tightly bond pieces of wood together? Many substances have been used as glues. Glues suitable for particle board include standard wood glue, polyurethane, super glues, and cement glues that instantly bind two materials together. These powerful glues create a bond that will stay in place even when others around it do not. It has to carry a lot of weight to not be used.

White glue is a relatively basic adhesive that holds small things, like paper, to surfaces. It is developed using the waste byproducts of animals, such as bones, ears, hooves, and tails. The byproducts are then boiled in a large container with zinc oxide until they begin to produce a glue-like substance. That substance is then bottled and sold commercially in the form of white glue. It is economically low, and we get it at the shop of a carpenter. (Ady Frenly Simanullang, 2021).

Physical properties of polyvinyl acetate

It is a white, odorless, and tasteless powder that dissolves in water to form a transparent solution. PVA is non-toxic and biodegradable. It has high tensile strength and a low melting point. I chose polyvinyl acetate adhesives for my experiment out of the adhesives mentioned above since they are readily available, reasonably priced, and biodegradable.

Advantages of polyvinyl acetate

- Easy to apply, and spreads
- Longer working time, about 30 minutes.
- Very strong edge-to-edge grain connections on wood.
- Certain varieties are waterproof and can be used outdoors.
- Water cleanup.
- Improve physical and mechanical strength.
- It is not expensive.
- Highly drying process.
- There is no toxicity or aging problem.

Disadvantages of wood glue

- Weak end-grain connections in wood
- Certain varieties cannot be used outdoors or in wet conditions.
- High water absorption.

3. MATERIALS AND METHODS

3.1. Materials

Raw Materials Collection and transportation: The main raw material required for this work was agricultural waste (maize cob).Corn cobs are available in most parts of Ethiopia, including Addis Ababa, and For this investigation, samples were gathered from Adama, Addis Ababa, and nearby villages. These studies have been carried out in the laboratories of the School of Chemical and Bio Engineering and the School of Mechanical and Industrial Engineering, Addis Ababa Institute of Technology. In addition, hardness of corncob particleboard was done in forest products innovation center of excellence.

Chemicals: The chemicals used to prepare maize cob particle board are listed below: Polyvinyl acetate adhesives are polymer materials having the chemical formula $C_4H_6O_2$. It is flexible, delivers a very strong bond, and is used as a wood adhesive. Oil is used to separate metal plates and corn cob particle boards. I used oil that is already in the mechanical workshop.

Equipment's: The lab equipment used in this study is indicated below:

A dryer (oven dryer): is a heated chamber used to remove water, moisture, and other solvents from objects. It was used to dry corn cob particle board.

Grinder machine (attrition mill): is used for reducing corn cob lumps to a "grain size" of minus 2mm to small particles.

Electronic scale: A devicethat accurately measures weight by generating an electric curre nt proportional to the displacement of a bowl. I used to measure all my corn cob samples.

Moisture Analyzer: The percentage of moisture content is determined by the difference in weight before and after drying. I only used it to measure the moisture content of corncob particle board.

Sieve: used to determines the gradation (the distribution of aggregate particles by size within a given sample) in order to determine compliance with design. I prepared the sample below 2mm by sieve analysis.(Abetie, 2021).

Metal molds: are tools for shaping. Molds are used in injection molding. I used this equipment for the shaping of the mixture and for pressing purpose.

Thermometer: A device used to measure the degree of heating of a mold. The material used for this type of temperature measurement is mercury in a graduated glass tube

Heating mantle (stove): used for heating the molds only.

Mortar: is a device that is used in laboratories to reduce the material size.

A manual hydraulic press: is a mechanical device that uses hydraulic pressure to crush and compress materials. These used in laboratories to prepare samples. I used Hydraulic presses for, molding Sluiter, A. *et al.* (2008).

Caliper: a device that is used to measure the distance between two opposite sides of an object. They are very simple measuring instruments and have an inward and outward point, just like a compass and I used for purpose of measuring the all sample dimension.(Abetie, 2021).

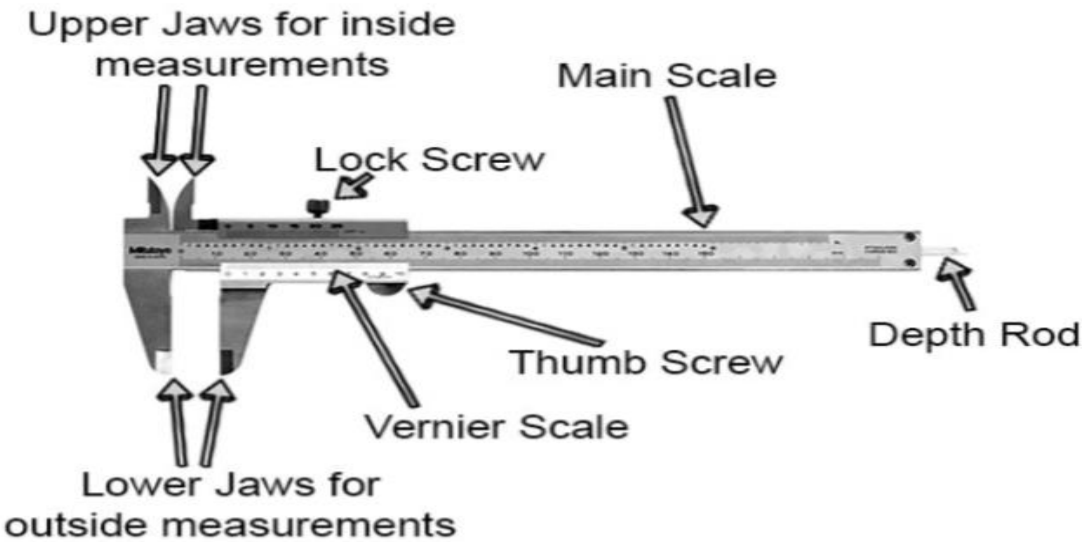

Figure 3.1: Parts of caliper

Crucible**:** A vessel used to melt substances, usually metallic elements, prior to casting. This demands extremely high temperature resistance, as well as outstanding chemical and physical stability. As a minimum, crucibles must have a melting point higher than that of the materials they contain. I used it during the experiment for the determination of ash content.(Abetie, 2021).

Figure 3.2: Crucible

Desiccators: are primarily used for the separation of liquids from appreciable amounts of solids. I used to cool my sample from oven without getting moisture.

Furnace: furnaces are broadly classified into two types: combustion (using fuels) and electric. I used the second one for forming ash and calculating of ash content.

Metal plates: can be defined as metals and alloys in the form of flat plates or metal plate stock.

It is used in a variety of applications, such as raw material feed for machines or the forming of parts, flooring fabrication, building, and construction materials. In this study, it was used to form mats.

Magnet: I used a manual magnet to separate raw material and metal.

3.2. Experimental Framework of the study

The framework of the experimental work was described in figure 3.3

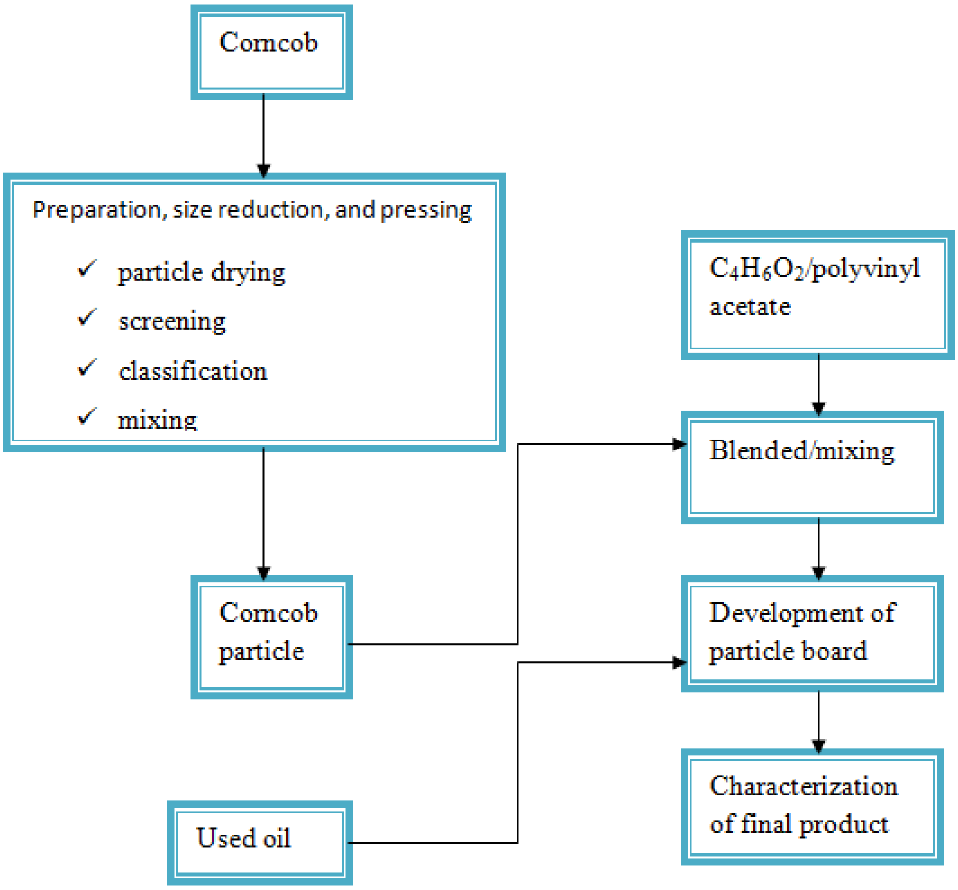

Figure 3.3: Experimental frame work of research

3.3. Experimental Methods

A. Preparing Raw Material

Sorting, classification, and removal of metallic and other contaminants.Before the log enters to this process it dries by using sunlight. This method makes the crushing process and also minimizes drying cost. I used a manual magnet to remove the metallic material from the collected corn cob. (shelf)

Figure 3.4: corn cobs before grinding

B. size reduction (mechanical unit operation)

This is the reduction of maize cob material to the desired particle size and shape. These processes take place by using attrition mill. First, the raw material enters to the attrition mill and it is crushed. Then the attrition crashes one log at a time. The size of the material released from the attrition is below 2mm. The aim is to manufacture a homogeneous product. Therefore, it needs to produce chips of a suitable size and shape of board to form the furniture. This is the reduction of maize cob material to the desired particle size and shape (shelf)Sluiter, A. *et al.* (2008).

Figure 3.5: Attrition mill and corn cob after grinding

C. **Particle dried**(Mass transfer unit operation)

Drying the particle is to predetermine and uniform moisture content. A source of heat and an agent to remove the vapor is sunlight.

D. **Particle classification and screening (**mechanical unit operation)

Screening is the practice of taking granular materials and separating them into classes based on particle size. We need to control particle size in order to make sure the size and position of the particles are in the right place, whether they are small particles or fine chips for all parts. The oversized, core, and fine particles are separated by screening. The oversized material was recycled back to the attrition mill to reduce its size and go back to the screen for sieving (shelf).

Figure 3.6: sieves and sieve machine

E. **Blended with PVA** (Mixing or Adding process)

Blending (addition or mixing) is the mixing of calculated amount of adhesive binder and other additives by spraying or other means. There are two blenders. An adhesive or glue will be applied to the surface of the particles to bind them all together.The binder used for blending is glue which is also called polyvinyl acetate in 30, 35, and 40 g.

F. **Forming**(Mechanical unit operation)

Forming is the process of forming the blended particles in to "mat" in the flat press process. Forming can be controlled so that the coarse particle in the furnish are placed in the center thickness of the board while fine particles are deposited closer to the surface (graduated layering) or the mat maybe laid as randomly deposited single layer mat producing homogeneous boards.

G. **Hot pressing** (Mechanical & Heat transfer unit operation)

Densification creates a surface between the mat's particles, and heat raises the adhesive line's temperature to a point where thermosetting resins may cure. Because of the low adhesive quantity and structural features, the pressure must provide good contact between the particles. Hot press has an influence on moisture change in the mat that takes place over the mat surface thickness. Apart from the pressure, temperature and time also forms other important parameters. Hot pressing to finally consolidate the board and cure the adhesive. I used the trial and error methods during press the mold (shelf).

Curing is the process of becoming hard or solid by cooling or drying.

If the press is not heated or heated in adequately, the pressure required for proper densification and development of reasonable contact area between particles will be high.

The basic function of pressing processes is primarily twofold:

-to polymerize the binder and

-to dandify the mass in to the desired thickness

Densification creates a surface between the particles in the mat (a temporary board created), and the heat raises the adhesive line's temperature to a point where thermosetting resins may cure. Because there is little glue used and the particles have mat structural features, the pressure must be exerted to create good contact between the particles. Hot press has an influence on moisture change in the mat that takes place over the mat surface thickness. Apart from the pressure, temperature and time also forms other important parameters.

H. **Cooling and finishing**(Heat exchange unit operation)

The cooling process takes place by using atmospheric air. In this section, the weight of the board is measured. Panels need to cool before finishing. After cooling, the boards are sanded to the final thickness and to a good surface finish. Cooling process is a physical operation in which heat is removed from process fluids or solids; may be by evaporation of liquids, expansion of gases, radiation or heat exchange to a cooler fluid stream, and so on. When the hot board emerged from the press preparatory operation such as cooling, trimming, and moisture equalizer may be performed.

3.3.1. Raw Material Analysis

3.3.1.2. Determination of lignin and cellulose

Extractives: 2.5g of dried biomass was loaded into the cellulose thimble. With the soxhlet extractor setup, 150ml of acetone was used as solvent for extraction. Residence times for the boiling, rising stages was carefully adjusted to 70^{o}c and 25min respectively on the heating mantle for a 4hr run period. After extraction, the sample was air dried at room temperature for few minutes. Constant weight of the extracted material was achieved in a convection oven at 105^{o}c. The percent of extractives content was evaluated as the difference in weight between the raw extractive laden biomass and extractive free biomass (D. Hyman, january 2008).

Hemicellulose Calculation

Saha, B. C., & Cotta, M. A. (2007).

The equation for calculating hemicellulose content is:

Hemicellulose =$Wsa{-}Wsb/Wsample{\times}100$

$$\text{Extractive} = \frac{\text{Wsb-Wsa}}{\text{Sample}} \times 100 \quad \text{......} 3.1$$

Where: Wsb – weight of sample before

Wsa- weight of sample after

$$\text{Extractive \%} = \frac{\text{Wsb-Wsa}}{\text{Sample}} \times 100 = \frac{3.6098\text{ g} - 3.4208\text{ g}}{2.5130\text{ g}} \times 100$$

$$= 7.52\ \%$$

Hemicellulose

1g of extracted dried biomass was transferred into a 250ml Erlenmeyer flask. 150 ml of 500mol/m^3 NaOH was added. The mixture was boiled for 3.5 hr with distilled water. It was filtered cooling through vacuum filtration and washed until neutral pH. The residue was dried to constant weight at 105^{o}cin a convection oven. The difference between the sample weight before and after this treatment is the hemicellulose content of dry biomass.

Hemi % = Wsa-Wsb x 100...3.2

Sample

Where: Wsb – weight of sample before

Wsa- weight of sample after

Hemicellulose%= $\frac{Wsa - Wsb}{Sample}$ x100 = $\frac{1.0527\ g - 0.7655}{1\ g}$ x100

= 28.72 %

Lignin

0.3g of dried extracted raw biomass was weighed in glass test tubes and 3ml of 72% H_2SO_4 was added. The sample was kept at room temperature for 2hr with carefully shaking at 30 min intervals to allow for complete hydrolysis. After the initial hydrolysis, 84 ml of distilled water was added. The second step of hydrolysis was made to occur in an autoclave for 1hr at 121^{o}c. the slurry was then cooled at room temperature. Hydrolyzates were filtered through vacuum using vacuum filtering. The acid insoluble lignin was determined by drying the residues at 105^{o}c. The acid soluble lignin fraction was determined by measuring the absorbance of acid hydrolyzed sample at 320 nm. The lignin content was calculated as the summation of acid insoluble lignin and acid soluble lignin (D. Hyman, january 2008).

AIL%= $\frac{Wsa-Wsb}{Sample}$ x100..3.3

Where: Wsb – weight of sample before

Wsa- weight of sample after

AIL-acid insoluble ligninSaha, B. C., & Cotta, M. A. (2007).

ASL%= $\frac{UVabs \times volume_{filtrate} \times dilution}{\varepsilon \times ODW_{sample} \times Path\ length}$ x100..3.4

Where: UVabs = average UV-Vis absorbance for the sample at appropriate wavelength, 0.493 L/g cm

Dilution, 1

Volume $_{hydrolysis\ liquor}$ = volume of filtrate, 87 mL

ε = Absorptivity of biomass at specific wavelength, 30

ODW_{sample}=weight of sample in milligrams, 300mg

Path length=path length of UV-Vis cell in 1cm

ASL-acid soluble lignin

$\%Lignin_{ext\ free}$= AIL%+ASL%..3.5

$$AIL\% = \frac{Wsa - Wsb}{Sample} \times 100 = \frac{1.5584g - 1.4895}{0.3g} \times 100$$

$= 22.96\ \%$

$$ASL\% = \frac{UV_{abs} \times volume \times dilution}{\varepsilon \times ODW_{s} \times path\ length} \times 100 = \frac{0.493\ L/g\ cm \times 87\ ml \times 1\ mg/ml}{30\ L/g\ cm \times 300\ mg \times 1\ cm} \times 100$$

$= 0.476566\ \%$

$\%Lignin_{ext\ free} = AIL\% + ASL\%$

$= 23.4432\ \%$

Cellulose

The cellulose content was calculated by difference, assuming that extractives, hemicellulose, lignin, and cellulose are the only components of the entire biomass.

$Cellulose\ \% = 100 - Lignin_{ext\ free} + Extractive + hemicellulose$

$= 100 - 23.4432 + 28.72 + 7.52$

$= 40.3168\ \%$

3.3.1.3. Maize Cop Particles' Moisture Content

Using the following findings: A quantity of the maize cob particles retained in sizes below 2mm and 1 g was weighed. By using the moisture analyzer in the lab (MB45 OHAUS, SWITZERLAND) the sample was tested.

Table 3:1 Factors and experimental levels using Design Expert version 6.0.8

Run no.	Temperature (^oc)	Pressure(bar)	Polyvinyl acetates(gm)
1	130	30	30
2	150	30	30
3	180	30	30
4	130	50	30
5	150	50	30
6	180	50	30
7	130	70	30
8	150	70	30
9	180	70	30
10	130	30	35
11	150	30	35
12	180	30	35
13	130	50	35
14	150	50	35
15	180	50	35
16	130	70	35
17	150	70	35
18	180	70	35
19	130	30	40
20	150	30	40
21	180	30	40
22	130	50	40
23	150	50	40
24	180	50	40
25	130	70	40
26	150	70	40
27	180	70	40

The basis to select the above parameters is:-

- The mold is prepared by the above composition
- The measurement of the temperatures that used during study is not count above the 180^o
- The pressing machine not automatic because of this I used the maximum pressure 70bar.
- I went to see the possibility of corncob with polyvinyl acetate adhesive to develop particle board by changing only the resin on Abetie, 2021 research.

3.3.2. Building a Particle Board from Maize Cobs

The method of preparing corn cobs into particleboards involves several critical steps to ensure optimal material properties. Initially, the maize cobs are reduced in size using a knife, followed by sun exposure to decrease their moisture content below 4.5%. Subsequently, the cobs are put for 24 hours at 100°C in an industrial oven hours, achieving a final moisture content of 3.52%. This drying process is crucial as it prevents the formation of excess moisture in the final product, which can lead to swelling and reduced structural integrity. Once dried, the maize cobs are ground using a mortar to achieve a finer particle size. For enhanced efficiency, an attrition mill machine is employed, which produces uniform fine particles essential for consistent bonding in particleboard fabrication. The resulting maize cob particles are then screened through sieving to ensure that all particles are below 2 mm in size. This uniformity in particle size is vital to avoid swelling and ensure even distribution of the binder throughout the mixture. Danladi, I. O. (2013).

In this study, the variable manipulated was the proportion of binders or hardeners applied, while maintaining a consistent mass of milled cobs at 39 g. The binder used in this research is polyvinyl acetate (PVA), which is known for its high reactivity, good performance, and cost-effectiveness. The mixture ratios adopted for the particleboard production were 60%, 65%, and 70% maize cob particles with varying amounts of PVA adhesive (30 g, 35 g, and 40 g).

To prepare the mixture, the fine maize cob particles and the specified amount of PVA are weighed using a precision scale. The components are then manually combined with a metal spoon and a wooden stirrer until well combined to ensure a homogenous blend. This thorough mixing is essential to achieve optimal adhesion between the maize cob particles and the binder.

The prepared mixture is then poured into a metal mold measuring 150 x 10^3 mm^3, with a steel plate positioned underneath to provide a flat surface for the particleboard. This mold design facilitates uniform pressure distribution during the pressing phase, which is critical for achieving the desired mechanical properties in the final product (Abetie, 2021).

Figure 3.7: Metallic mould and plates

The moisture content of particleboards can be influenced by various factors, including temperature, pressure, and the type of binder used. In your query, it is noted that the minimum moisture content was found to be 8.106% at 130°C, 70 bar, and 40 g of PVA, while the maximum moisture content reached 15.397% at 180°C, 50 bar, and 30 g of PVA. The average moisture content across all boards was reported as 11.75%. (Abetie, 2021).

Relationship between Temperature and Moisture Content

1. **Increased Temperature and Moisture Content**: Higher temperatures during the particleboard production process can lead to increased moisture content for several reasons:

   - **Thermal Degradation**: At elevated temperatures, the thermal degradation of the biomass can occur, resulting in the release of moisture that was previously bound within the material. This can lead to an increase in the overall moisture content of the final product.

- **Binder Behavior**: The behavior of the binder, in this case, polyvinyl acetate (PVA), can also change with temperature. As the temperature rises, the viscosity of PVA may decrease, allowing for better penetration into the maize cob particles. However, if the temperature is too high, it may lead to incomplete curing or excessive evaporation of moisture, which can affect the final moisture content.

- **Evaporation**: While higher temperatures generally promote moisture evaporation, if the process is not well-controlled, it can lead to uneven drying and moisture retention in some areas of the particleboard.

2. **Equilibrium Moisture Content**: The equilibrium moisture content (EMC) of the particleboard is primarily influenced by the relative humidity of the environment. According to Moslmi (1974), the moisture content at grain boundaries typically ranges from 8% to 12%, which is considered acceptable for wood particleboards. However, as the temperature increases, the ability of the material to retain moisture may change, potentially leading to higher moisture content if the boards are not adequately dried or if they absorb moisture from the environment.

3. **Implications for Particleboard Performance**: Higher moisture content in particleboards can adversely affect their mechanical properties, such as flexural strength and water absorption. This is particularly important for applications where moisture exposure is expected, as higher moisture content can lead to swelling, reduced strength, and overall degradation of the particleboard.

In summary, while higher temperatures can facilitate certain processes in particleboard production, they can also lead to increased moisture content due to thermal degradation, changes in binder behavior, and potential evaporation issues. It is crucial to optimize the production parameters to achieve the desired moisture content while ensuring the mechanical properties of the particleboards are maintained.

Figure 3.8: manually hydraulic press machine

Curing is the process becoming hard or solid the material by cooling or drying.

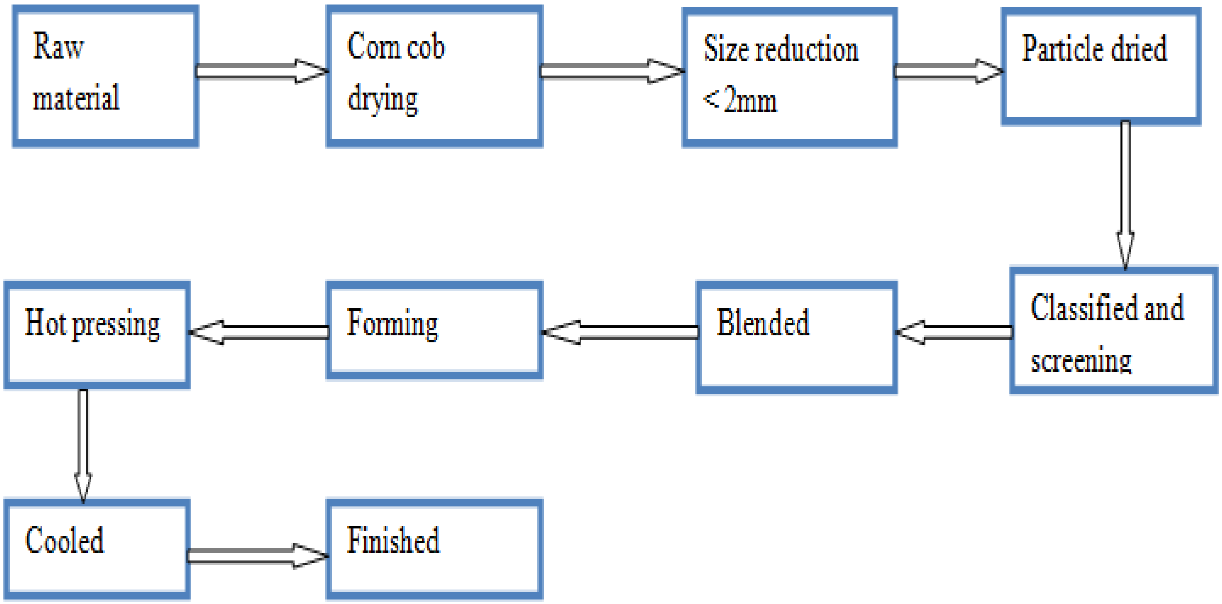

Figure 3.9: Diagrams representing the experimental flow used to create maize cob particle boards.

3.3.3. Characterization of the Physico-Mechanical Properties of Particleboard

3.3.3.1. Characterization of the Physical Property of Particle Board

3.3.3.2. Mat moisture content

Once the hot press is closed, the surface of the mat piles immediately adjacent to the hot press & rapidly rises in temperature approaching that of the platen. The moisture content, another gradient is established somewhat with reverse pattern compared to that of the temperature. The moisture content gradient quickly develops because water begins to migrate rapidly from hot surfaces of compressed mat towards cooler interior layers. The migration of moisture from the mat surface towards the core is an important phenomenon. Rapid movement of steam towards the mat interior will accelerate the heating of the core, there by facilitating a faster resin cure in the core section of the mat.

3.3.3.4. Determination of Density of Particle board

Density (Kg/m3) = Wa/Va...3.8

Wa weight after air drying
Va air-dried capacity

Volume of Particle Board = l x h x 3.9

where l = length

h = height

w = width (Abetie, 2021).

3.4. Experimental Design and statistical analysis

The production of maize cob particleboards can indeed yield a total of 27 different particleboard samples, as indicated by the experimental design utilized in the study. This design was based on a general factorial design (GFD) approach, which allows for the systematic evaluation of multiple factors and their interactions.

Data analysis for this study was conducted using DESIGN EXPERT version 6.0 software (version 6.0.8), employing an evaluation of the impacts of several process factors using a general factorial design (GFD) on the compression strength of particleboards fabricated from maize cob. The key process variables included temperature (set at three levels: 130°C, 150°C, and 180°C), pressure (30 bars, 50 bars, and 70 bars), and the polyvinyl acetate (30 g, 35 g, and 40 g). A constant amount of corncob particles, specifically 39 g, was maintained throughout the experiments.

The experimental design consisted of 27 distinct trials, based on the factorial pattern the software produced, each with one replicate. This design approach is beneficial for optimizing process parameters that are assessed at multiple levels, thus minimizing experimental errors and enhancing accuracy in the results.

To evaluate the significance of the findings, an analysis of variance (ANOVA) was performed, allowing for a comprehensive understanding of how each variable influences the response variable, which in this case is the yielding compression strength post-fabrication. The details of the experimental setup and the results of the analysis are summarized in Table 3.1, demonstrating the systematic approach taken in this research to optimize the production of particleboards from maize cob using polyvinyl acetate (PVA) adhesive. This methodology not only contributes to the efficiency of the manufacturing process but also aligns with sustainable practices by utilizing agricultural waste, thereby addressing environmental concerns associated with traditional wood-based particleboard production (Abetie, 2021).

4. RESULTS AND DISCUSSION

Results and discussion on the manufacturing and characterization of particleboard utilizing PVA glue and maize cob were examined in this section.

4.1. Raw Material Characterizations

4.1.1. Determination of lignin and cellulose

Table 4.1: composition of different extraction in corn cob

Composition of corn cob	Averages%
Extractive	7.52%
Acid in lignin	22.96%
Acid soluble lignin	0.476566%

Determination of Lignin

Content Lignin of maize cob binds to cellulose fibers to harden and strengthen cell walls of plant and percentage of measurement of lignin was 23.4432% nearest to 25% that is an acceptable range. According to According to Chow et al. (2008), the standard value of lignin content of wood is 25 -35%.

Determination of Cellulose

Percent cellulose content was calculated using ASTM D 2017–98 with the following formula. According to Zubairu, (1989), the maize cobs average percent of cellulose is 40.3168%.

As Zubairu, 1989 the softwood percent constituents of cellulose, lignin, and hemicellulose was 42-49 %, 25-30% and 24-30%. The corncob composition of above three main constituents was :-

Table 4.2:Composition of corncob

Corncob constituents	Average in %
Cellulose	40.3168
Hemi-cellulose	28.72
Lignin	23.4432

Almost corn cob particle have good composition of cellulose, lignin, and hemicellulose as we see from the table 4.2.

4.1.2. Moisture Content of Maize Cop Particles

The moisture content of maize cob particles was moisture analyzer in the lab (MB45 OHAUS, SWITZERLAND) calculated using According to Zubairu (1989), the moisture content of particles was described as 3.5%.

4.2. Physical Property Tests of Particle Boards

4.2.1. Particle board made of maize cob thickness

It was discovered that the typical measured thickness of maize cob particle board was be 7.825mm. This value is within the acceptable range for particleboards, which typically vary between 6-10mm in thickness (Abetie, 2021). The minimum and maximum values of 6.325mm and 9.325mm, respectively, were observed under different experimental conditions.

These conditions included varying temperatures (150°C) and pressures (30 bars and 70 bars) along with different polyvinyl acetate (PVA) contents (40 gm). The variation in thickness can be attributed to the differences in impregnation ratios and pressures used during the particleboard production process. The thickness of the particleboard is an important physical property that affects its overall performance. The results also indicate that the thickness of the particleboard can be controlled by adjusting the impregnation ratio and pressure during production. This is an important consideration for manufacturers, as it allows them to tailor the thickness of their products to specific requirements. For example, thinner particleboards may be preferred for applications where weight is a concern, while thicker boards may be needed for applications where strength and durability are critical (Abetie, 2021).

4.2.2. Density of particle board

The density of the particleboards is another important factor, affecting their strength and weight. The density of the boards produced from maize cob varied according to the adhesive ratio and processing conditions.

It was noted that the difference in experimental composition and the addition of impregnation ratio had some effect on the board density. From the experimental results, the minimum density was 407.384kg/m^3 (130^{o}c, 70 bar, and 40 gmPVA), the maximum density was 642.944 kg/m^3 (150^{o}c, 50 bar, and 40 gmPVA), and the mean density was discovered to be

525.164 kg/m^3.

4.2.3. Moisture Content

The percentage of moisture content, the minimum moisture content for the particle board was found to be 8.106% at 130^{0}C, 70bar, and 40 gm PVA, and the maximum was 15.397% at 180^{0}C, 50bar, and 30 gm PVA. This parameter is crucial as it affects the durability and performance of the boards in different environmental conditions.

4.2.4. Water Absorption Test

The ability of the boards to absorb water is an important property, influencing their performance in humid conditions. The water absorption rates varied significantly based on the composition and processing conditions The water absorption of almost all samples of corn cob particles at room temperature and polyvinyl acetate has been significantly absorbed, and nearly all samples were soluble within 30 minutes. Because it absorbed a lot of water, the corn cob particle board had a high water absorption rate. Due to this, it can be used for indoor applications in dry seasons. From the experiment, the least value of WA times (180^{o}c, 70 bar, 35 gm PVA, and30 minute immersion) was 37.44%.

Table 4.3: The product's physical property summary (particle board made of maize and cob)

Run. No	T(^{0}C)	P(bar)	PVA(gm)	Th(mm)	ρ(kg/m^{3})	Moisture content (%)	Water Absorption (%)
1	130	30	30	6.675	573.782	14.402	86.42
2	150	30	30	7.300	463.013	14.559	60.02
3	180	30	30	7.300	542.465	13.914	64.09
4	130	50	30	7.850	473.885	14.653	93.07
5	150	50	30	7.625	482.622	14.305	94.4
6	180	50	30	7.200	526.388	15.397	71.35
7	130	70	30	7.575	433.003	10.410	90.78
8	150	70	30	7.450	485.906	14.182	100.03
9	180	70	30	6.925	525.631	13.288	76.08
10	130	30	35	7.350	508.843	13.953	75.24
11	150	30	35	7.450	436.241	14.279	92.07
12	180	30	35	6.400	515.625	15.339	78.02
13	130	50	35	6.875	584.727	15.027	84.40
14	150	50	35	7.525	549.466	13.741	91.00
15	180	50	35	8.575	413.994	13.956	45.00
16	130	70	35	7.075	498.939	14.487	83.33
17	150	70	35	6.600	487.878	12.350	91.33
18	180	70	35	7.550	425.165	12.816	37.44
19	130	30	40	6.975	554.838	11.292	57.02
20	150	30	40	6.325	475.889	13.964	88.38
21	180	30	40	7.150	518.881	12.280	82.28
22	130	50	40	7.750	440.000	13.415	40.06
23	150	50	40	8.150	642.944	11.642	56.25
24	180	50	40	7.000	502.857	11.308	56.02
25	130	70	40	8.125	407.384	8.106	85.45
26	150	70	40	9.325	531.903	12.389	78.62
27	180	70	40	7.850	566.878	12.220	68.5

From above table 4.3 the average of thickness is 7.4 mm, this result slightly good as we see many factories in our country particle board thickness (8-12mm). The thickness variation happen on above table because of the effect of the mold and press machine, that means mold have its own effect on the particle thickness also the pressing machine is not auto because of this the value on the table is vary. As ASTM the density of particle board was divided into three, low density 300-400 kg/m^3, medium density (400-800 kg/m^3), and high density particle board. As my study see that the density of corncob particle board almost all of them has in medium particle density.

In summary, the maximum and minimum values for temperature, pressure, and PVA ratio in the experimental design should be based on a combination of literature review, material properties, preliminary experiments, process optimization techniques, environmental considerations, and industry standards. This comprehensive approach ensures that the experimental design is robust and capable of producing high-quality particleboards from maize cob.

4.3. Mechanical Property Determination of Particle Board

4.3.1. Flexural strength

Flexural strength is a measure of the maximum load-carrying capacity of a given species in bending strength and is proportional to the breaking point or maximum strength as borne by the specimen. It measures the bonding strength of the test specimen and can be used to determine a corn cob particle board species overall strength. The strength of the boards is a key indicator of their structural integrity. The results showed varying flexural strengths depending on the process parameters used.

Where: -

- Pre constant force-21N
- Preload speed: -50mm/min
- Machine maximum load: -1 kN
- Th- Thickness
- Flexural strength **($\sigma = FL / Wd^2$)**
- W- Width
- Flexural Strength (Bending Stress)

- t- Time
- L- Load
- PVA-Polyvinyl Acetate
- T-Temperature
- P-Pressure
- d-depth

Figure 4.1: Texture Analyser Machine.

Table 4.4: Mechanical Property of PB

Run	t (sec)	T(^{0}c)	P (bar)	PA(gm)	depth(mm)	Width(mm)	Load(N)	σ(Mpa)
1	20.06	130	30	30	4.59	32.23	95.40	2.9514
2	16.30	150	30	30	5.09	37.00	136.20	2.984
3	12.28	180	30	30	4.79	30.94	101.00	2.9913
4	21.24	130	50	30	6.09	35.39	99.80	1.5972
5	16.79	150	50	30	6.35	33.13	110.60	1.7388
6	12.64	180	50	30	5.80	29.41	50.16	1.0648
7	17.52	130	70	30	6.60	27.21	59.19	1.0487
8	10.41	150	70	30	5.15	31.15	47.54	1.2085
9	10.84	180	70	30	6.93	31.52	82.57	1.1456
10	10.99	130	30	35	6.33	33.47	101.00	1.5895
11	22.77	150	30	35	6.95	32.65	141.23	1.8806
12	17.68	180	30	35	5.77	32.60	89.62	1.7342
13	23.22	130	50	35	7.06	29.78	80.47	1.1386
14	25.19	150	50	35	6.49	29.65	65.32	1.0985
15	22.77	180	50	35	7.18	26.45	84.91	1.3077
16	19.59	130	70	35	4.79	31.16	83.86	2.4635
17	36.79	150	70	35	3.35	31.95	38.00	2.2304
18	19.78	180	70	35	5.51	27.24	85.22	2.1642
19	25.65	130	30	40	7.90	35.20	227.39	2.1737
20	19.92	150	30	40	2.58	27.19	23.41	2.717
21	26.24	180	30	40	2.31	29.10	16.22	2.1941
22	15.39	130	50	40	4.93	23.84	58.05	2.1041
23	17.84	150	50	40	6.04	31.24	138.63	2.5546
24	17.17	180	50	40	4.95	31.55	81.47	2.2133
25	18.31	130	70	40	4.05	24.13	59.22	3.1424
26	8.84	150	70	40	5.99	30.17	180.66	3.5049
27	26.64	180	70	40	4.00	26.31	75.38	3.7605

Table 4.5: Comparison of mechanical properties of different result(Abetie, 2021)

Properties	Wood + urea formaldehyde	Corn cob + modified starch	Corn cob + PVA
Flexural strength	12-18Mpa	0.132 Mpa	3.7605Mpa
Moisture content	6.5%-9%	11.43%	11.75%
Water absorption	60%-120%	29.54%	34.77% -100%
Density	750-850kg/m^3	7828.16kg/m^3	407.384kg/m^3-642.944kg/m^3

The data shows that particleboards made from wood with urea formaldehyde have higher flexural strength (12-18 MPa) and lower moisture content (6.5%-9%) compared to those made from corn cob with modified starch or PVA. However, corn cob particleboards have lower densities, which can be advantageous for certain applications. It's important to note that the properties of particleboards can vary depending on factors such as the specific composition, manufacturing process, and testing methods used in each study. In addition above table we absorb the study of different person by using corncob and wood dust and different adhesive and its properties. Almost moisture content of the three above particle board has slightly difference. When we see the water absorption particle board manufactured from modified starch it has low water absorption but other adhesive that we see in the table above has almost the same water absorption. Another one is density of the particle developed from urea formaldehyde and modified starch has equal amount of density value, but PVA particle board has low density when we see the two adhesive.

4.3.2. Hardness

Test Hardness measurement is the resistance of a sample of MC particle board to denting and wear. It measures the force required to embed a steel ball halfway into the sample size of 2.5x4.5mm to determine whether the board is suitable for a ceiling roof. On the side of MC, most materials show increasing hardness with increasing density, fitting well with the impact of density on hardness (ASTM Roell M.FOS.013 and ASTM D1037-06a). Furthermore, increasing press temperature leads to higher hardness.

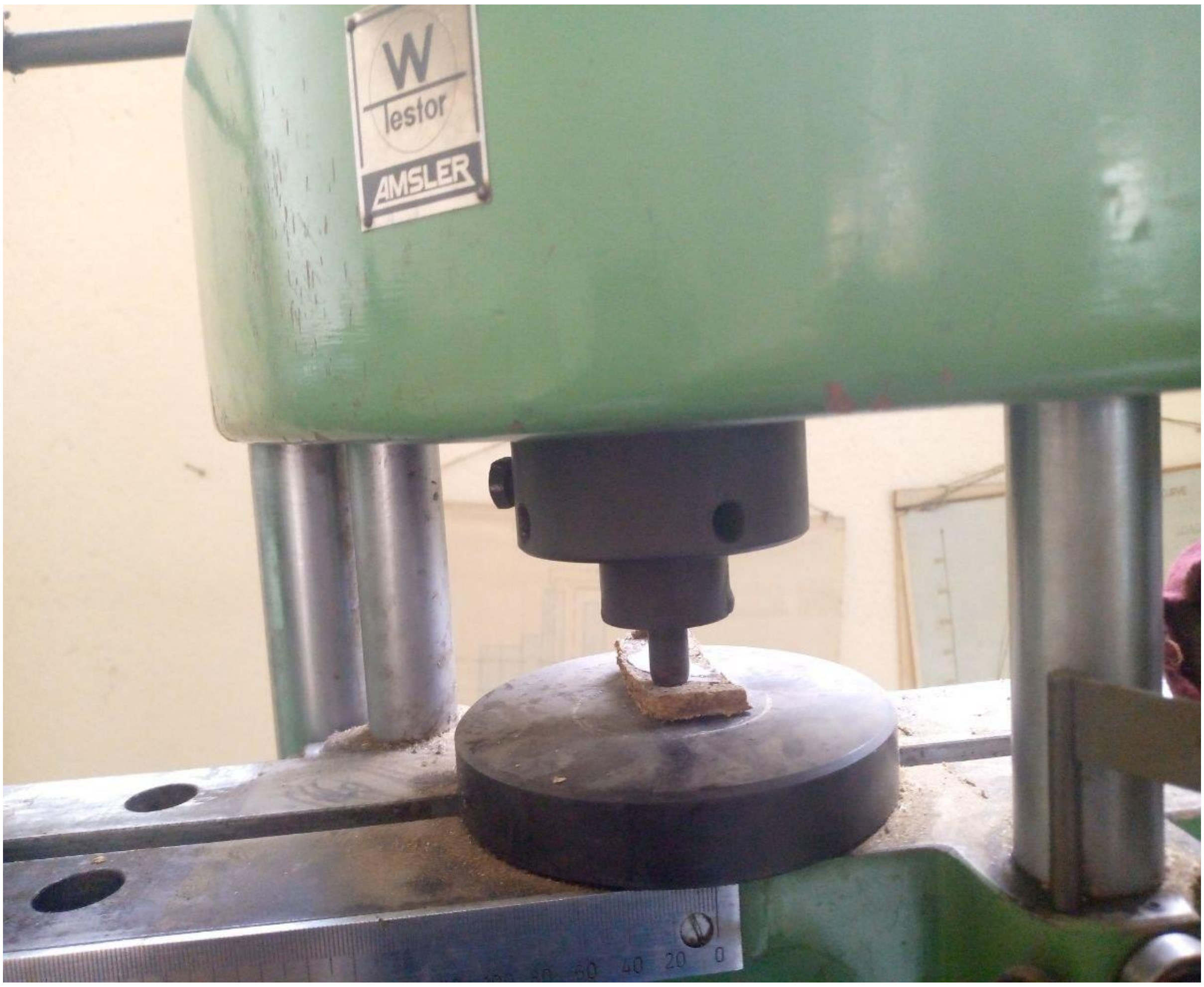

Figure 4.2: Hardness measuring setup of particle board(ASTM Roell, M.FOS.013, and ASTM D1037-06a).

At 130°C press temperature, 70 bar and 40 gPVA were found to have good hardness, i.e., 2930N. According to ASTM Roell, M.FOS.013, and ASTM D1037-06a, the hardness was closest to 2930N since particle board above 2930N has a good hardness.

Table 4.6: Hardness of corn cob particle board

Sample Number	Sample code	Dimension		Resistance to Indentation (N)
		Width(mm)	Thickness(mm)	
1	130,30,30	32.33	4.59	2750
2	150,30,30	37.00	5.09	2910
3	180,30,30	30.94	4.79	2450
4	130,50,30	35.39	6.09	1400
5	150,50,30	33.13	6.35	980
6	180,50,30	29.41	5.80	710
7	130,70,30	27.21	6.60	2330
8	150,70,30	31.15	5.15	1650
9	180,70,30	31.52	6.93	980
10	130,30,35	33.47	6.33	1750
11	150,30,35	32.65	6.95	2210
12	180,30,35	32.60	5.77	1200
13	130,50,35	29.78	7.06	2350
14	150,50,35	29.65	6.49	1640
15	180,50.35	26.45	7.18	2200
16	130,70,35	31.16	4.79	1540
17	150,70,35	31.95	3.35	2190
18	180,70,35	27.24	5.51	1610
19	130,30,40	35.20	7.90	1660
20	150,30,40	27.19	2.58	1060
21	180,30,40	29.10	2.31	1750
22	130,50,40	23.84	4.93	800
23	150,50,40	31.24	6.04	2250
24	180,50,40	31.55	4.95	2900
25	130,70,40	24.13	4.05	2930
26	150,70.40	30.17	5.99	1800
27	180,70,40	26.31	4.00	2750

4.4. Statistical Analysis for flexural analyses of Particleboard

A= Temperature of the mold and plate
B = Pressure; C = PVA

AB = The relationship between plate pressure and temperature, and the mold.

AC is the result of the interplay of PVA, plate temperature, and mould.

BC is the result of the interaction of PVA and pressing pressure.

Response: Flexural strength

ANOVA for Selected Factorial Model

Analysis of variance table [Partial sum of squares]

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model	15.77	18	0.88	18.51	0.0001
A	*0.18*	*2*	*0.090*	*1.90*	*0.2115*
B	*2.80*	*2*	*1.40*	*29.53*	*0.0002*
C	*5.05*	*2*	*2.52*	*53.30*	*< 0.0001*
AB	*0.10*	*4*	*0.025*	*0.53*	*0.7166*
AC	*0.22*	*4*	*0.054*	*1.15*	*0.4014*
BC	*7.43*	*4*	*1.86*	*39.26*	*< 0.0001*
Residual	0.38	8	0.047		
Cor Total	16.15	26			

Std. Dev.	0.22	R-Squared	0.9766
Mean	2.10	Adj R-Squared	0.9238
C.V.	10.36	Pred R-Square(	0.7329
PRESS	4.31	Adeq Precision	13.652

The PVA ratio, the interaction between mould and plate temperature and pressing pressure, the interaction between pressing pressure and PVA ratio but the main effects the interaction between mould and plate temperature, pressure and PVA ratio affects the flexural analyses. From these statistical tests, it found that the model was adequate for predicting PVA of maize cob particleboard within the range of variables.

The Model F-value of 18.51 implies the model is significant.There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise.Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case B, C, BC are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

The "Pred R-Squared" of 0.7329 is in reasonable agreement with the "Adj R-Squared" of 0.9238."Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 13.652 indicates an adequate signal. This model can be used to navigate the design space.

Final equation in terms of coded factors:

Flexural strength=+2.10-0.077*A[1]+0.11*A[2]+0.26*B[1]-0.45*B[2]-0.24*C[1]-0.37*C[2]-0.042*A[1]B[1]+0.057*A[2]B[1]+0.044*A[1]B[2]+0.038*A[2]B[2]+0.084*A[1]C[1]+5.222 E-003*A[2]C[1]+0.073*A[1]C[2]-0.11 * A[2]C[2]+0.86* B[1]C[1]+0.062* B[2]C[1]-0.26 * B[1]C[2]-0.099* B[2]C[2]

Table 4.7: Actual and predicted values of flexural strength of particleboard

Std run	Temprature	Pressure	PVA	Actual	Predicted	Residual
1	130	30	30	2.95	2.94	0.011
2	150	30	30	2.98	3.15	-0.17
3	180	30	30	2.99	2.84	0.16
4	130	50	30	1.60	1.52	0.080
5	150	50	30	1.74	1.62	0.12
6	180	50	30	1.06	1.26	-0.20
7	130	70	30	1.05	1.14	-0.091
8	150	70	30	1.21	1.16	0.051
9	180	70	30	1.15	1.11	0.040
10	130	30	35	1.59	1.69	-0.099
11	150	30	35	1.88	1.79	0.087
12	180	30	35	1.73	1.72	0.013
13	`130	50	35	1.14	1.22	-0.083
14	150	50	35	1.10	1.22	-0.12
15	180	50	35	1.31	1.10	0.21
16	130	70	35	2.46	2.28	0.18
17	150	70	35	2.23	2.19	0.037
18	180	70	35	2.16	2.38	-0.22
19	130	30	40	2.17	2.09	0.088
20	150	30	40	2.72	2.64	0.080
21	180	30	40	2.19	2.36	-0.17
22	130	50	40	2.10	2.10	3.467E-003
24	180	50	40	2.21	2.22	-0.011
25	130	70	40	3.14	3.23	-0.092
26	150	70	40	3.50	3.59	-0.088
27	180	70	40	3.76	3.58	0.18

4.5. Model Adequacy Check

A line of unit slope, i.e., a line of perfect fit with points corresponding to zero error between predicted values and actual values, is also shown in Figure 4.3. This plot, therefore, shows the performance of the correlation in an obvious way. The results in Figure 4.3 demonstrated that the regression model equation provided a very accurate description of the experimental data, in which all points are very close to the line of perfect fit. This result indicates that it was successful in capturing the correlation between the three-particle board production process variables and the bending strength.

The adequacy of the model was further checked with the analysis of variance (ANOVA), as shown in Table 4.3. Based on a 95% confidence level, the 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 1, and it is likely that any of the factors have a significant effect on the response with a P-value greater than 0.05. It was calculated by dividing the model mean square by the residual mean square. Here, the model F-value of 18.51 implies the model is significant. The "Model F value" of 18.51implies the model is significant relative to the noise. There is only a 0.01% chance that a "Model F-value" this large could occur due to noise.

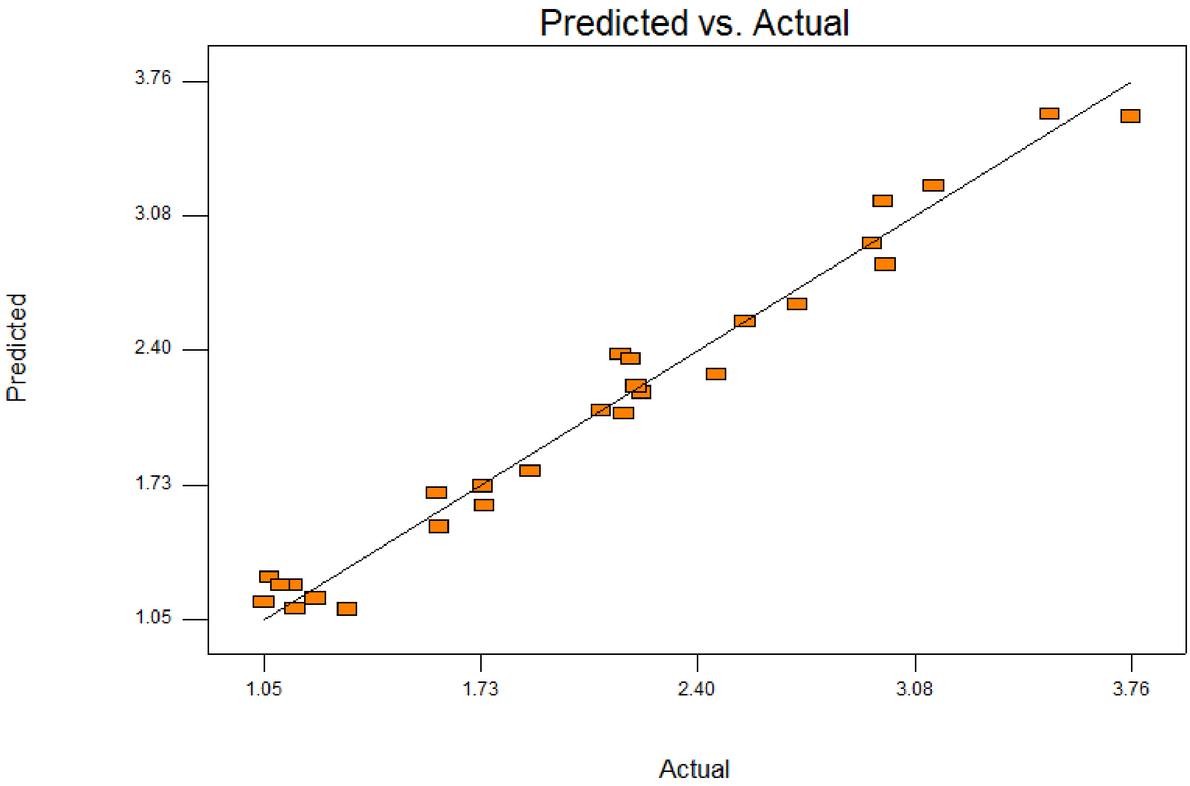

Figure 4.3: Predicted versus the actual flexural strength of MC particleboard.

There was a line of perfect match, with points denoting zero pure error between the internal bonding values that were anticipated and those that were observed. As a result, this plot clearly illustrates how well the correlation performed.

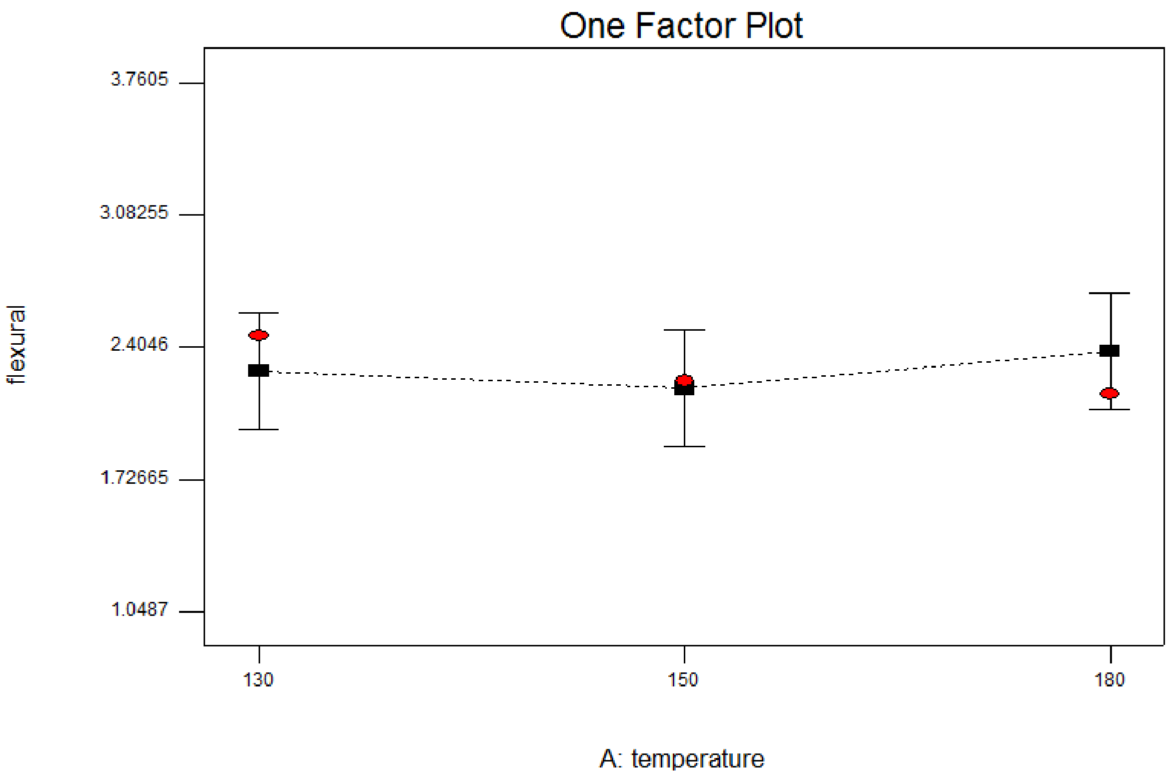

Figure 4.4: The impact of temperature on particleboard flexural strength.

The red color point on figure 4.4 denoted a model's design pints. The flexural strength of MC particle board is influenced by temperature; when the temperature rises from 130^{0}C to 180^{0}C the flexural strength the same after 150^{0}C the flexural strength and the temperatures were sligthly decrease. Generally when we see the design point on figure 4.4 as flexural strength incrasethe temperature was sligthly decrease to 180$^{o}_{c}$.

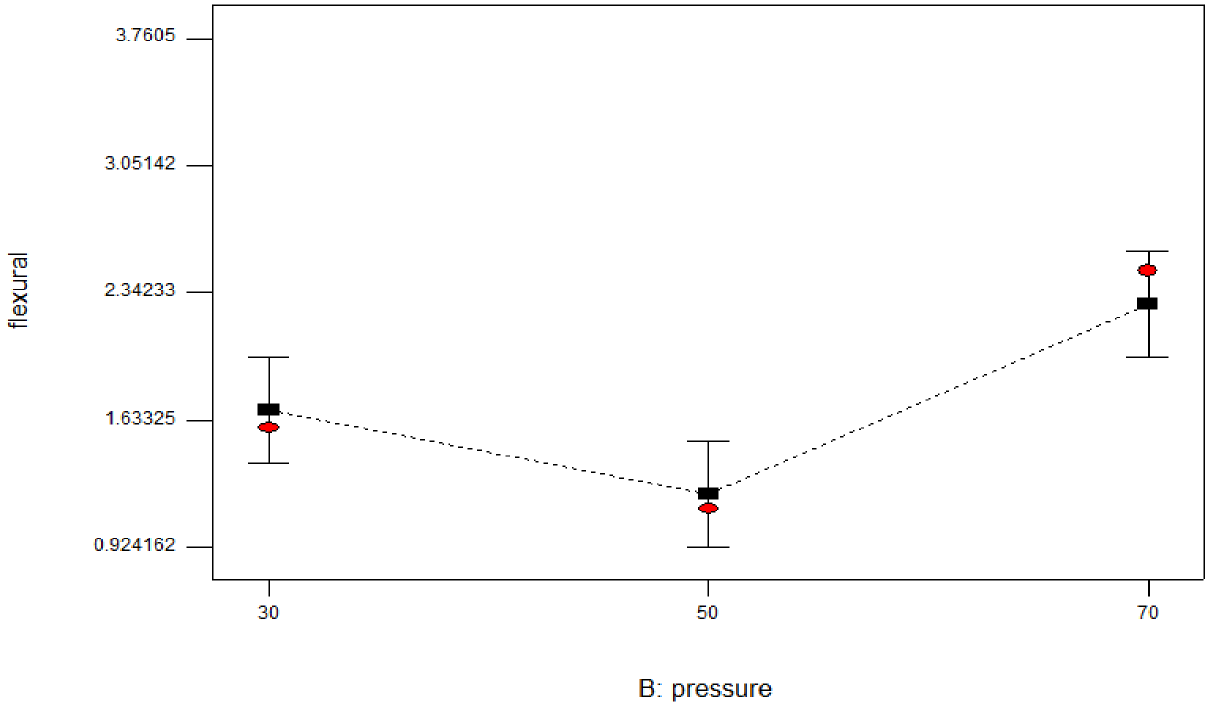

Figure 4.5: The impact of pressure on particleboard's flexural strength.

The red color point on figure 4.5 denoted a model's design pints. There was pressure increase at 30bar and decrease up to 50bar. After 50bar pressure and flexural strength increased proportionally.

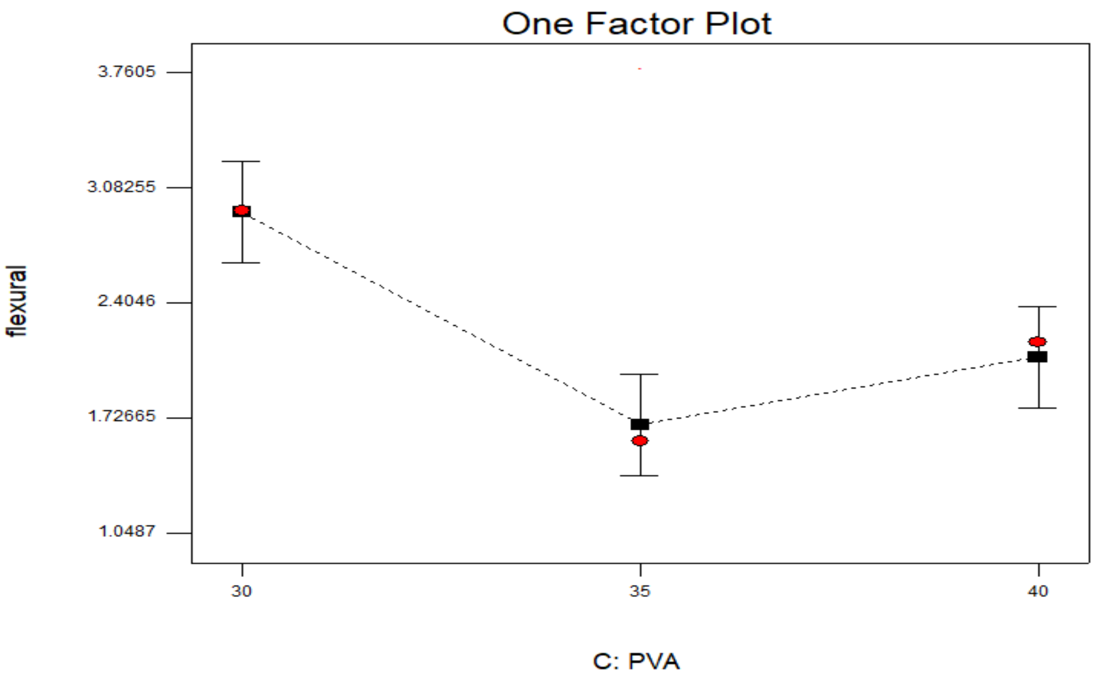

Figure 4.6: The effect of PVA in the flexural strength of particleboard.

Figure 4.6 above shows that the red color point denotes a model's design pints. The flexural strength is decrase from 30 g up to 35 g of polyvoniyly acetate. when flexural strength 1.72665 the PVA is 35 g. After 35g PVA the flexural strength was slithly increase to 2.4046 Mpa. In general adhesive have it own effect on the flexural strengh.

4.6. Optimization of particle board produced from corn cob and PVA

Numerical optimization is one of the core methods of machine learning. For many problems, it is difficult to find the optimal solution directly, but it is relatively easy to set up a loss function that measures how good the solution is and then find the solution by minimizing the parameters of that function.

Table 4.8: Constraints of Numerical Optimization of Corncob Particle

Constraints						
Name	**Goal**	**Lower Limit**	**Upper Limit**	**Lower Weight**	**Upper Weight**	**Importance**
temperature	is in range	130	180	1	1	3
Pressure	Is in range	30	70	1	1	3
PVA	Is in range	30	40	1	1	3
Flexural	is target = 2.4046	1.0487	3.7605	1	1	3
Thickness	Is in range	2.31	7.9	1	1	3
Density	Is in range	407.384	642.944	1	1	3
WA	Is in range	37.44	100.03	1	1	3
Mc	Is in range	8.106	15.397	1	1	3

Table 4.9: Solution of optimum constraints

Solution							
Number	**Temperature**	**Pressure**	**PVA**	**Density**	**Thickness**	**flexural**	
1	180	70	35	450.547	5.31111	2.38362	**selected**
2	180	30	40	544.4	2.62778	2.36239	
3	130	70	35	477.282	4.31778	2.28096	
4	150	50	40	604.826	5.75444	2.54693	
5	180	50	40	508.853	4.40444	2.22443	
6	150	70	35	484.154	4.02111	2.19352	
7	150	30	40	495.833	4.24444	2.63686	
8	130	50	40	472.122	5.76111	2.10063	
9	130	30	40	509.375	5.91778	2.08556	
10	180	30	30	571.226	4.31444	2.83588	
11	130	30	30	560.395	5.65111	2.94014	
12	150	30	35	431.671	5.87111	1.79407	
13	180	30	35	461.345	5.92778	1.72133	
14	130	30	35	567.693	7.25111	1.6889	
15	150	30	30	447.639	4.50444	3.15068	
16	150	50	30	512.446	6.22778	1.62306	
17	130	70	40	420.725	5.20111	3.23401	
18	130	50	30	478.956	5.70778	1.51752	
19	180	50	30	491.493	6.30444	1.26022	
20	180	70	40	535.363	4.22778	3.58108	
21	150	50	35	557.76	6.89778	1.22191	
22	150	70	40	550.077	4.61111	3.59271	
23	150	70	30	471.457	5.85778	1.15757	
24	180	70	30	531.764	6.90111	1.1056	
25	180	50	35	442.893	7.22111	1.10114	

5. CONCLUSIONSAND RECOMMENDATIONS

5.1. Conclusions

The purpose of the study was to use the compression method to create a particleboard from corn cob and polyvinyl acetate and to examine how the blend ratio and resin content affected the finished board's characteristics. The study's findings allow for the following conclusions to be made.

The study successfully produced particleboards from maize cob using polyvinyl acetate (PVA) adhesive. The particleboards exhibited acceptable mechanical properties, including flexural strength, hardness, and water absorption. The study optimized the production process by identifying the optimal conditions for producing particleboards with acceptable mechanical properties. These conditions included a temperature of 180°C, pressure of 70 bars, and PVA content of 40 g. The study characterized the particleboards' mechanical and physicochemical characteristics, including density, moisture content and dimensional stability. These properties were found to be within the acceptable range for particleboards. The property of the particleboard is a function of the percentage composition of the components. This means that the properties of plywood depend on the ratio of resin and filler. As a result, changing the composition ratio changes the properties of plywood. You can make plywood using corn cobs using polyvinyl acetate as a binder.

5.2. Recommendations

Commercialization of Particleboards: The study recommends commercializing the production of particleboards from maize cob and PVA adhesive. This could lead to the development of new industries and create employment opportunities.

Further Research: The study recommends further research to improve the mechanical properties of the particleboards and to explore other applications for maize cob and PVA adhesive and also on parameters composition.

Environmental Benefits: The study highlights the environmental benefits of using maize cob and PVA adhesive for particleboard production, including reduced waste generation and the use of renewable resources.

Cost-Effective Production: The study recommends optimizing the production process to reduce costs and increase efficiency. This could be achieved through the use of automation and the optimization of raw material usage.

Standardization of Particleboard Production: The study recommends standardizing the production process to ensure consistent quality and properties of the particleboards. This could be achieved through the development of guidelines and standards for particleboard production.

REFERENCES

A. Danladi, I. O. (2013). Mechanical Properties of Particle Boards from Maize Cob and Urea-Formaldehyde Resin. World Academy of Science, Engineering and Technology .

Abdallah, S. (2006). Effect of blending lignocellulosic material and resin level on .

Abetie, D. (2021). Particle Board production from maize cob.

Ady Frenly Simanullang, 2. S. (January 2021). Analysis Of Mechanical Testing Of Particle Board Composites From Corn Cobs Waste With Isocyanate Epoxy Resin Adhesive. International journal of scientific & technology research volume 10 .

Ajiwe, V. O. (1998). A pilot plant for production .

Bhatnagar, S. (1994). " Fire and Rice Husk Particleboard", Fire and Materials, vol. 18, .

Bode Haryanto, I. T. (2023). Natural adsorbent of corncob (Zea mays L.) powder capability in purification of used cooking oil with shaking operation based on turbidity. Results in Engineering .

Brinkmann, H. (1979). Annual Plants and Wastes from Debarking As Raw Material . Springe, West Germany.

Dien, B. S. et al. (2006) - This research focuses on the conversion of agricultural residues into value-added products, including particleboards, and discusses the role of PVA in enhancing the properties of these materials.

D. Hyman, A. S. (january 2008). Determination of Acid Soluble Lignin Concentration Curve by UV-Vis Spectroscopy. National Renewable Energy Laboratory .

Deppe, H. a. (2000). Taschenbuch der Spanplattentechnik. DRW-Verlag Weinbrenner Gmb H & Co., . Leinfelden-Echterdingen (Germany).

Evaluation of particle board from sugarcane and corn cob. (2019). International Journal of mechanical Engineering and Technoogy.10(01), , 1193-1200.

Gadea, A. (2010 (spain)). Maize cob boards (MCB).

H, R. F. (1997). Encyclopaedia of Science and Technology 8th edition. 257.

Holz als Roh- und Werkstoff, 2. (. (1963). Der Einfluss der Spanabmessungen auf einige Eigenschaften von . In G. Rackwitz. Germany.

John Wiley and Sons, I. (2005). Design and Analysis of Expert. In Montgomery (6 ed.).

kuntz, l. (2009). Project report, Fachagentur Nachwachsense Rohstoffe, Güstrow. Untersuchungen zur Verbesserung der technologischen und .

Kumar, A. et al. (2020) - This study investigates the use of agro-waste materials, including maize cob, in composite production and evaluates the mechanical properties of the resulting particleboards.

Leight, J. (. The Timber Trade, Pergamon Press London, .

Leiva P., C. R. (2007). Medium-Density. pp. Vol. 106,1301–1306.

Mantel, C. (1975). Solid waste origin, collection, processing and disposal, . New York,USA .

Moslemi, A. (1974). Particleboard, Volumes (1), materials. Southem Illinois university .

Ndazi, B. K. (2007). Chemical and physical . In applied science and manufacturing (pp. vol. 38, 925-935).

Pinto J, C. D. (2012). Characterization of corn cob as a possible raw building material.

project report,fachagentur nachwachsense rohstoffe,gustrow. (2009).

Sluiter, A. et al. (2008) - This technical report from the National Renewable Energy Laboratory (NREL) outlines standardized methods for analyzing biomass, including the extraction of cellulose and lignin, which are critical for understanding the composition of maize cob in particleboard applications.

shelf, E. (2020). ,What is particle board? How particle board is made?

Watson, S. A. (1987). Corn: Chemistry and technology. Wiley-VCH.

Wong, E. (1999). Formation of the density profile and its effects on the properties of .

(1999). Formation of the density profile and its effects on the properties of particleboard. In E. Wong, Wood Science and Technolog (pp. 327 – 340).

Zhang, Y. et al. (2018) - This paper explores the development of eco-friendly particleboards using various agricultural residues and discusses the potential of PVA as a sustainable adhesive option.

Zubairu, I. K. (1989). The Suitability of Maize Cobs for the Production .

APPENDIX I: Characterization Part

Hardness of corn cob particle board test

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The Federal Democratic Republic of Ethiopia
Ethiopian Forestry Development
Forest Products Innovation Center of Excellence

ቀን 5/6/2016
Date
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ለገመቹ ሀይለማርያም

ጉዳዩ፡- ትብብር የተደረግንላቸዉ ናሙና ፍተሻ ዉጤት መስጠት ይሆናል

ጥር 22 ቀን 2016 ዓ.ም በቁጥር SCBE-/2016 በተፃፈ ደብዳቤ የ'Corncob particleboard' ናሙና hardness test እንዲፈትሽላቸዉ ትብብር በጠየቁን መሰረት ፍተሸዉ ተካሂዶ 3 ገጽ የፍተሸ ዉጤት በዚህ ደብዳቤ ሸኝት ጋር የሰጠን መሆኑን እንገልፃለን፡፡

ከሠላምታ ጋር

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P.O.Box: 2322
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universal Test machine ASTM D1037-06a

11.3mm diameter of 0.444 inch hemispherical end of steel bar

Hardness Test Data Sheet

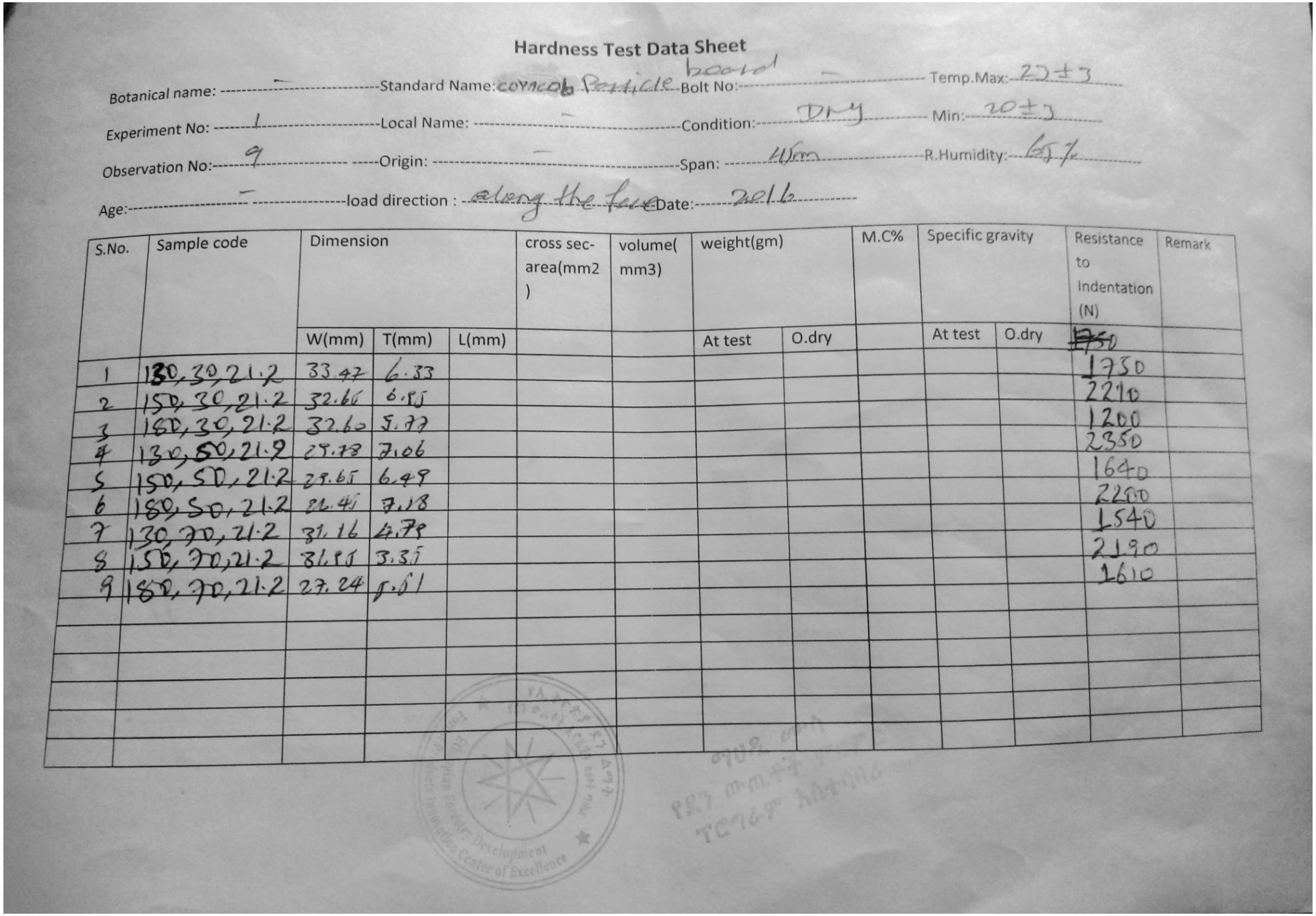
Botanical name: – Standard Name: corncob particleboard Bolt No: – Temp.Max: 23±3

Experiment No: 1 Local Name: – Condition: Dry Min: 20±3

Observation No: 9 Origin: – Span: 40mm R.Humidity: 65%

Age: – load direction : along the face Date: 2016

S.No.	Sample code	Dimension			cross sec-area(mm2)	volume(mm3)	weight(gm)		M.C%	Specific gravity		Resistance to Indentation (N)	Remark
		W(mm)	T(mm)	L(mm)			At test	O.dry		At test	O.dry	~~2960~~	
1	130,30,16.8	32.33	5.18									2,750	
2	150,30,16.8	37.00	5.09									2810	
3	180,30,16.8	30.84	4.79									2450	
4	130,50,16.8	35.39	6.09									1400	
5	150,50,16.8	33.13	6.35									980	
6	180,50,16.8	29.41	5.80									710	
7	130,70,16.8	27.21	6.60									2330	
8	150,70,16.8	37.15	5.16									1650	
9	180,70,16.8	31.52	6.93									980	



Hardness Test Data Sheet

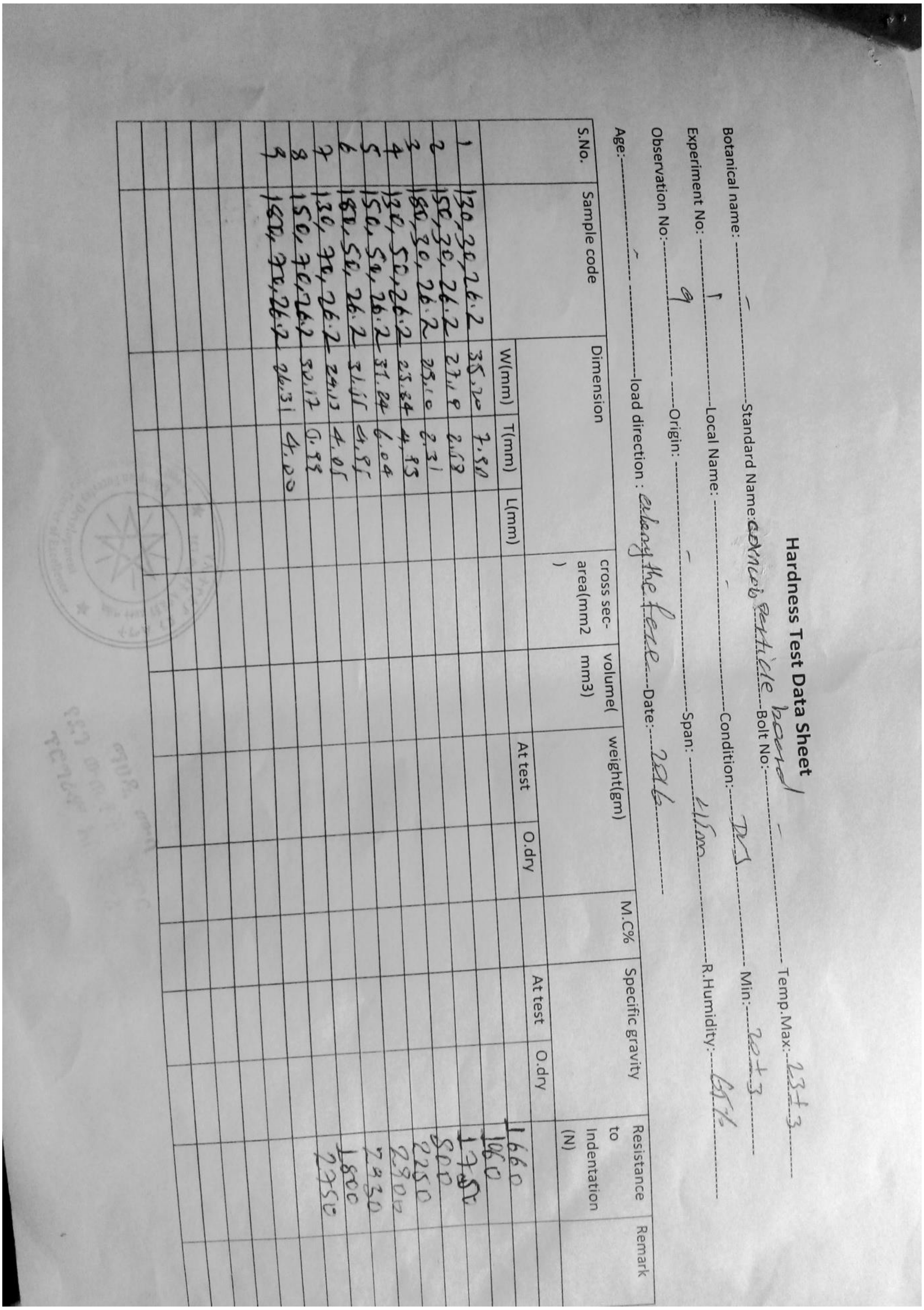
Botanical name: – Standard Name: corncob Particle board Bolt No: – Temp.Max: 23±3

Experiment No: 1 Local Name: – Condition: Dry Min: 20±3

Observation No: 9 Origin: – Span: 4/cm R.Humidity: 65%

Age: – load direction : along the face Date: 2016

S.No.	Sample code	Dimension			cross sec-area(mm2)	volume(mm3)	weight(gm)		M.C%	Specific gravity		Resistance to Indentation (N)	Remark
		W(mm)	T(mm)	L(mm)			At test	O.dry		At test	O.dry	~~1750~~	
1	130,30,21.2	33.47	6.33									1750	
2	150,30,21.2	32.66	6.55									2210	
3	180,30,21.2	32.60	5.77									1200	
4	130,50,21.2	29.73	7.06									2350	
5	150,50,21.2	29.65	6.49									1640	
6	180,50,21.2	32.45	7.18									2200	
7	130,70,21.2	31.16	4.79									1540	
8	150,70,21.2	31.55	3.35									2190	
9	180,70,21.2	27.24	5.61									1610	



Hardness Test Data Sheet

Botanical name: – Standard Name: cement bonded particle board Bolt No: – Temp.Max: 23±3

Experiment No: 1 Local Name: – Condition: DRS Min: 20±3

Observation No: 9 Origin: – Span: 415mm R.Humidity: 65%

Age: – load direction : along the face Date: 2016

S.No.	Sample code	Dimension			cross sec-area(mm2)	volume(mm3)	weight(gm)		M.C%	Specific gravity		Resistance to Indentation (N)	Remark
		W(mm)	T(mm)	L(mm)			At test	O.dry		At test	O.dry		
1	130,30,26.2	35.20	7.80									1660	
2	150,30,26.2	27.19	2.58									1060	
3	180,30,26.2	23.10	2.31									1750	
4	130,50,26.2	23.84	4.93									800	
5	150,50,26.2	31.24	6.04									2250	
6	180,50,26.2	31.55	4.95									2900	
7	130,70,26.2	24.13	4.05									2330	
8	150,70,26.2	30.17	0.98									1800	
9	180,70,26.2	26.31	4.00									2750	

Table i: Ash content of corn cob particle board

Run no	W0(gm)	W1(gm)	W2(gm)	W2-W0(gm)	W1-W0(gm)	Ash %
1	34.640	37.640	34.737	0.097	3	3.23
2	38.728	41.728	38.837	0.109	3	3.63
3	36.311	39.311	36.414	0.103	3	3.43
4	38.641	41.641	38.751	0.110	3	3.66
5	39.418	42.418	39.508	0.090	3	3.00
6	35.503	38.503	35.599	0.096	3	3.20
7	41.364	44.364	41.462	0.098	3	3.26
8	44.056	47.056	44.154	0.098	3	2.46
9	29.493	32.483	29.567	0.074	3	1.36
10	23.627	26.627	23.668	0.041	3	3.26
11	23.650	26.650	23.748	0.098	3	1.53
12	41.715	44.715	41.761	0.046	3	2.90
13	58.759	61.759	58.846	0.087	3	3.30
14	61.166	64.166	61.265	0.099	3	3.86
15	34.640	37.640	34.756	0.116	3	3.73
16	38.728	41.728	38.840	0.112	3	4.80
17	36.311	39.311	36.455	0.144	3	4.40
18	38.641	41.641	38.774	0.133	3	4.00
19	39.418	42.418	39.538	0.120	3	3.96
20	35.503	38.503	35.622	0.119	3	4.00
21	41.364	44.364	41.485	0.121	3	3.76
22	44.056	47.056	44.171	0.115	3	3.50
23	29.493	32.493	29.598	0.105	3	3.80
24	23.627	26.627	23.741	0.114	3	4.96
25	23.650	26.650	23.799	0.149	3	4.26
26	41.715	44.715	41.843	0.128	3	3.60
27	58.759	61.759	58.858	0.109	3	2.06

Table ii: Composite of corn cob, PVA, and wood sand particle board properties.

No	T (^{0}c)	P (bar)	PVA(gm)	Textural (MPa)	Thickness (mm)	Density (Kg/m^3)	mc (%)
1	150	50	35	5.9806	8.675	629.366	11.504

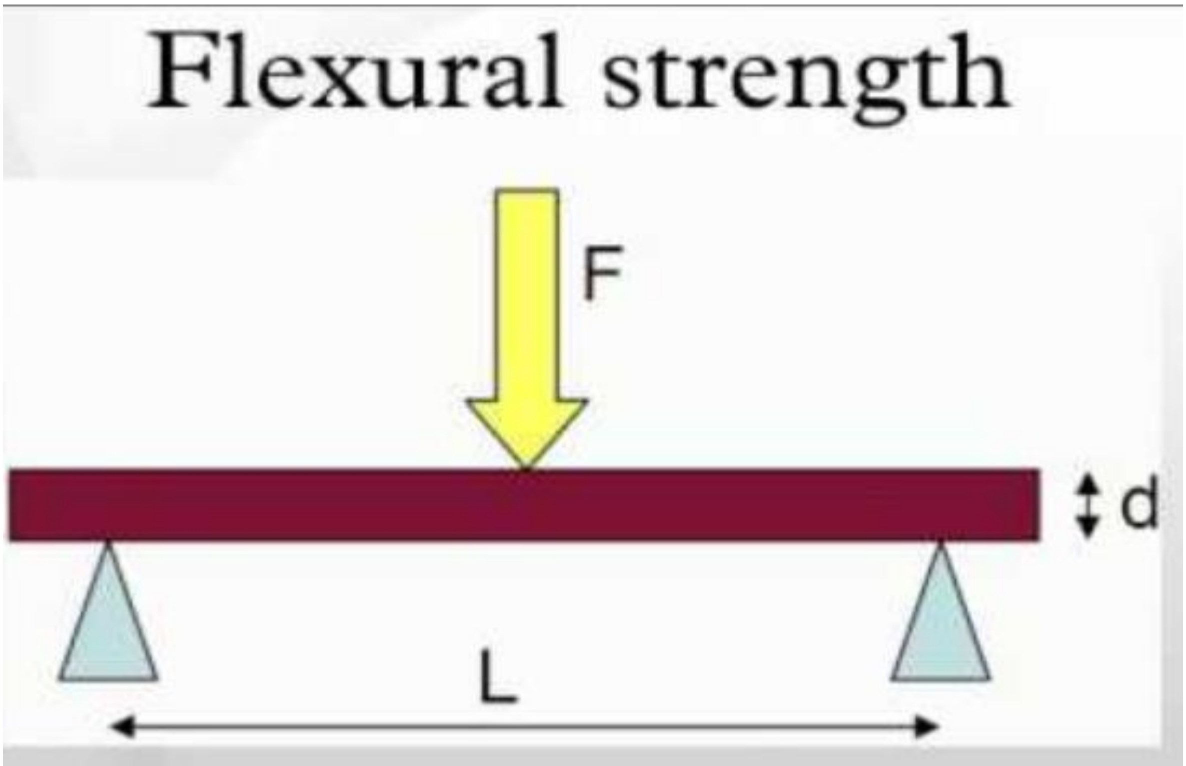


Figure i: flexural strength

Appendix II:Laboratory Chemicals and Equipments

Size Reduction and Stove

Press machine and blending

Oven and dissectors

Furnace and inner part of furnace

Electronic beam balance and Crucibles

Flexural Analysis Machine

Universal test machine

CC particle board sample

Figure ii: Experimental laboratory equipment.

Corncob particle board that is ready for characterization

APPENDIX III: Design Expert Plot 6.0.8 Version interaction graph

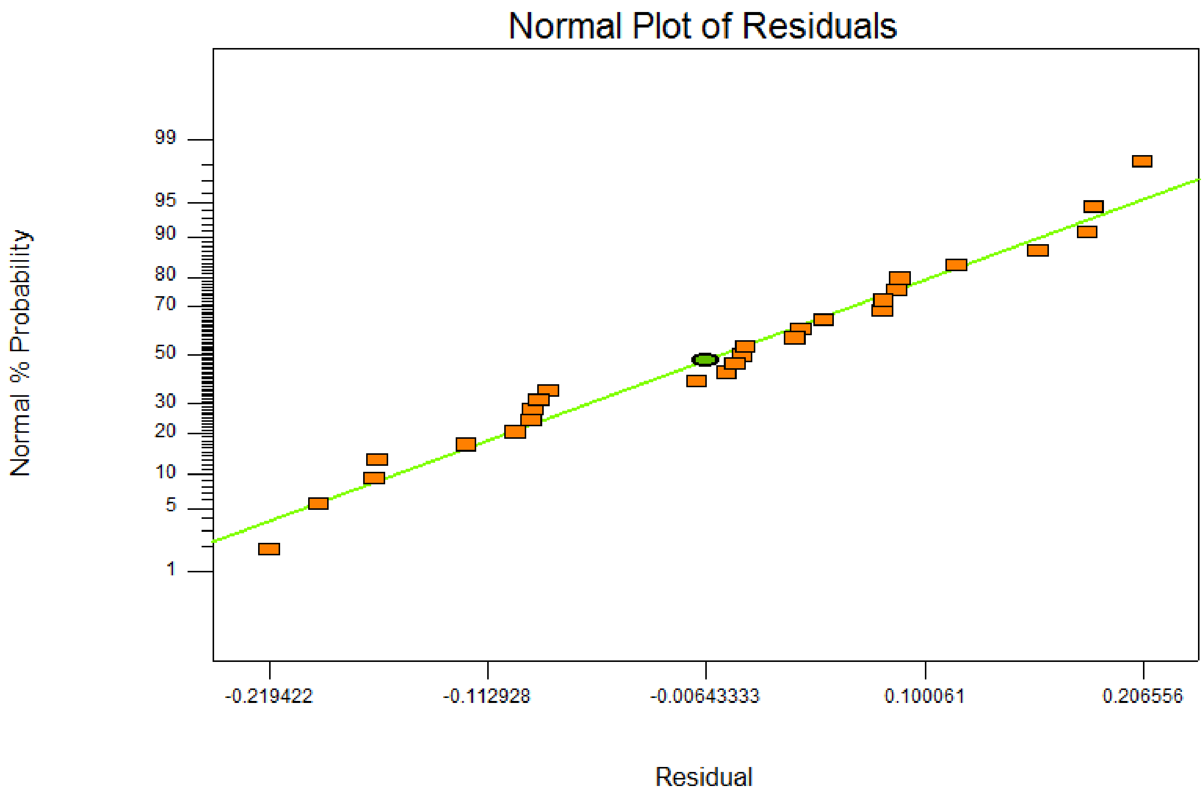


Figure i: The interaction effects of normal % probability and Residual PB

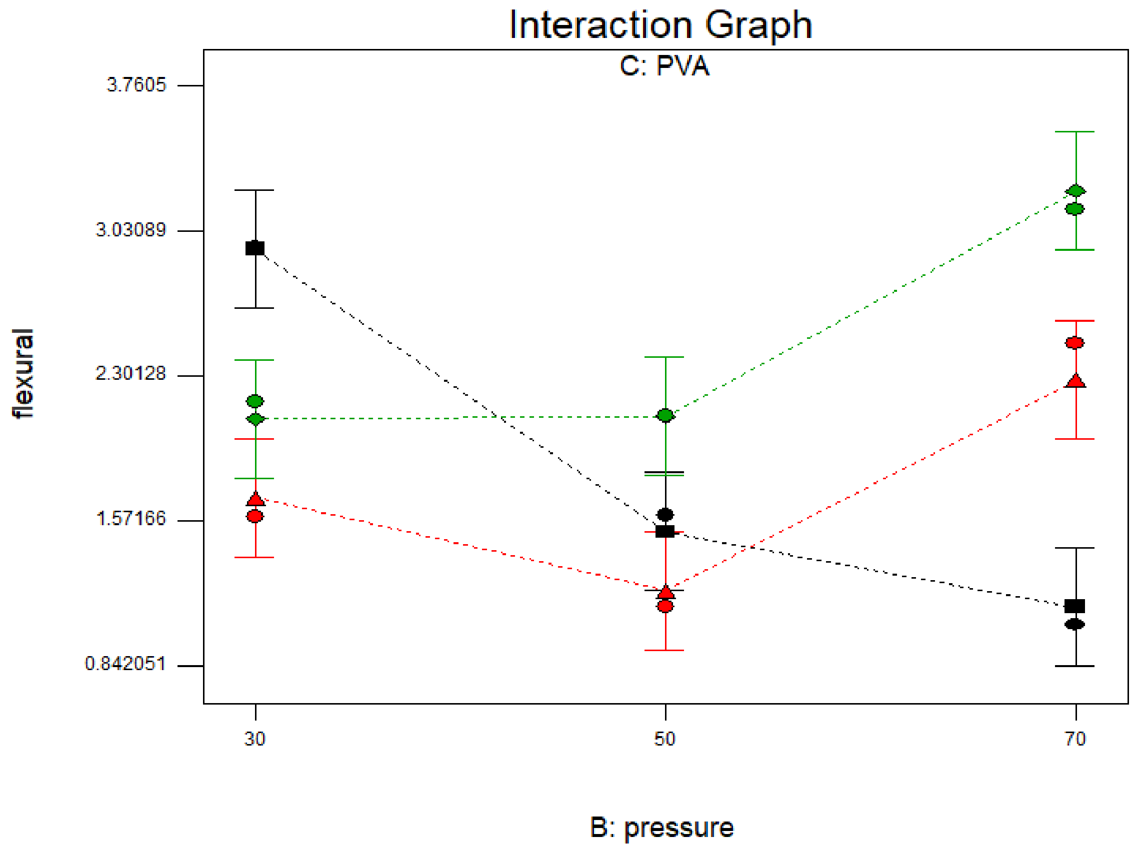


Figure ii: The interaction effects of pressure and flexural strength.

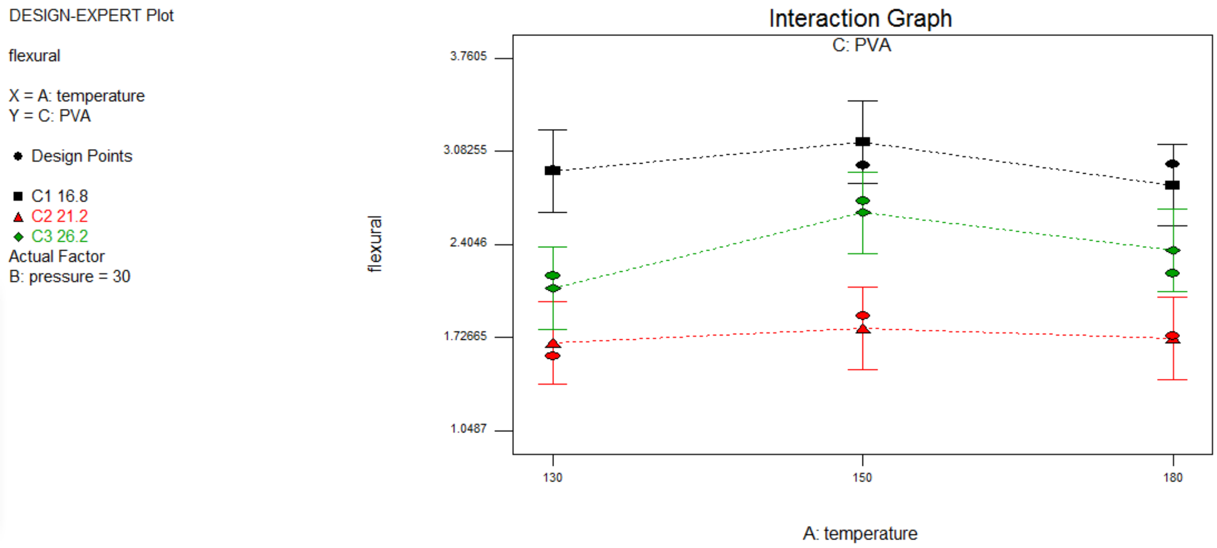


Figure iii: The interaction effects of starch ratio and temperature on internal bonding Maize Cob Particle Board

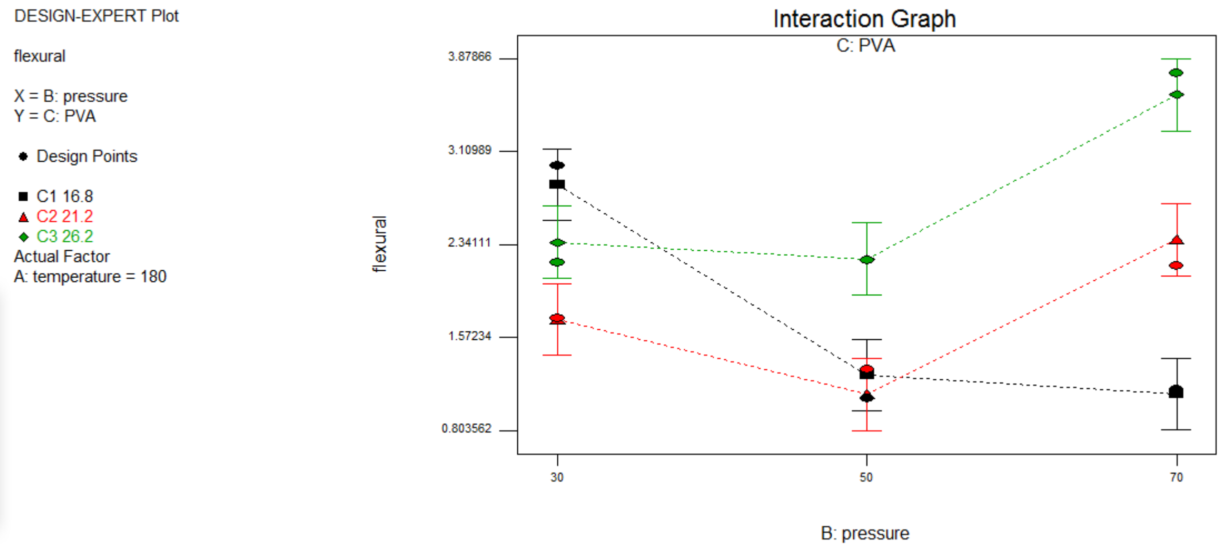


Figure iv: The interaction effects of pressing pressure on internal bonding Maize Cob Particle Board