A Study on Low Density Polyethylene (LDPE) Sawdust Composites

by

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Dissertation submitted in partial fulfilment of

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CERTIFICATION OF APPROVAL

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Approved by,

____

(Dr Maziyar Sabet)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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NURIZZATI BINTI RAMLI

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ABSTRACT

Sawdust is very useful to replaced wood to meet human essential but sawdust itself has several characteristics that became a barrier that make it cannot be commercially used. Hence, this research project will prepare the sample of low density polyethylene sawdust composite and explore more about the application for the waste of wood and to find out how the polymer can improve the properties of sawdust. In this study two types of parameters had been used. The experiment will be conducted according to the different in the range of sawdust particles size and different composition of the sample. The range of sawdust particles size divided into four which are sample A, B, C and D with different composition of LDPE:sawdust. Several types of tests had been conducted to test on the properties of the LDPE sawdust composites. In water absorption test, sample C with 90:10 compositions shows the best result of 2.18% of weight gained. The density determination shows that sample A with the composition of 90:10 have the best result of 523.89kg/m3 while for thickness swelling determination, sample D with the composition of 90:10 shows the best result of 6.12%. The tensile strength test, shows the best sample is sample C of 90:10 composition loading with the tensile strength value of 5.78 N/mm2 while for flexural test the best sample is also sample C of 90:10 composition loading with a flexural strength of 10.98MPa. For the SEM, it shows that there are differences in the microstructure for different range of sawdust particles size used and different composite loading that affected the mechanical strength of the sample. All the experiment shows the positive result on mechanical and physical properties of the composite with the introduction of LDPE and it can be concluded that sample C with 90:10 composition loading shows the best results. There are higher potential for LDPE sawdust composites to replace wood-based product but several improvement should be implemented in terms of sample preparation and time as well as more research on other type of polymer used should be done.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Since the ancient time, wood had been one of the essential materials for human survival. The reason is because it is wide abundance in number, renewable and environmentally benign. As the time goes by, the uses of wood had been undergone several revolution as it had been used as shelter, fuel, tools, boats, vehicles, bridges, furniture, engineering materials, weapons, and even raw materials for energy. Now, it is widely used in various aspects of human life.

However, due to the increasing in the demand of wood itself, the production of high-quality wood has been fleetly decreasing and the supply cannot meet the market demand. Plus, the reforestation of the trees in order to meet the needed of human being causes a lot of environmental problem and habitat issues for the animals. Therefore, the researchers try to find the alternatives materials that can replace wood. One of the solutions to solve the problem of the rapid increment of the wood consumption year by year is by introducing the uses of sawdust or also known as wood dust.

Sawdust is a by-product of cutting, grinding, drilling, sanding, or otherwise pulverizing wood or by product of certain animals, birds and insects that composed of fine particles of wood. It is used for particleboard, including serving as mulch, as an alternative to clay cat litter, or as a fuel. Sawdust can be found easily and cheap. Generally, sawdust has the same properties as the wood that it comes from. Nowadays, sawdust is widely used as fuel and as the wood-base board. This is because it has several characteristics like absorbent, as for liquid spill cleanup, mud control, floor coverings, sweeping compounds, or as a carrier of liquid manure abrasive, as in hand soaps, metal polishes, fur cleaners, or sweeping compounds, bulky and fibrous, as for wood flour, cushioning, packaging, or lightweight cement aggregate, nonconductive as for insulation; and granular, as for textured surfaces.

As sawdust had been chosen as the alternative to replace wood in various industry, some of the characteristics of sawdust like it density, porosity, permeability, thermal conductivity and many more, all the mechanical properties and strength need to be improved by inventing a sawdust composite polymer.

In this study, low density polyethylene (LDPE) had been chosen as the polymer to be used in order to enhance the mechanical properties and strength of the sawdust by introducing the low density polyethylene (LDPE) sawdust composites. This is due to it is easy to get and cheaper.

1.2 Problem Statement

Due to the vast range of the uses for sawdust, specific researches have to be done to improvise the mechanical properties and strength of the sawdust so that it can be commercially used in various industries. Several factors based on the properties of the sawdust such as the density, porosity, permeability, thermal conductivity and many more causes the limitation of it use and lead to the less quality product to be produced. In order to improve the mechanical strength and properties of sawdust, Low Density Polyethylene (LDPE) has been used to form Low Density Polyethylene (LDPE) sawdust composite. Therefore, during this study, the effects of the addition of polymer towards several mechanical properties and strength of the sawdust composite polymer will be analysed and being compared with the raw sawdust.

1.3 Objective of Study

This research is carry out based on two objectives:

i. *To find the application for the waste of wood.*
ii. *To prepare a sample of LDPE sawdust composites.*
iii. *To find out how the polymer can improve the properties of sawdust.*

1.4 Scope of Study

From the research, below are several things that need to be cover in this study:

i. *The properties of sawdust.*
ii. *The properties of low density polyethylene (LDPE).*
iii. *Preparing the sample for LDPE sawdust composites.*
iv. *The differences and advantages of sawdust polymer composites as compared to wood polymer composites.*
v. *Conducting the mechanical and physical tests on the raw sawdust and sawdust polymer composites.*

CHAPTER 2

LITERATURE REVIEW

2.1 Sawdust

Sawdust is also known as wood waste which composed of the fine particles of the wood. It is a by-product of the wood due to the pulverizing wood with a saw or other tool, cutting, grinding, drilling and sanding. It is also can be produced from certain animals, birds and insects which live in wood, such as the woodpecker and carpenter ant. Figure 1 shows an example of sawdust.

Figure 1: Sawdust

Sawdust has several health and safety issues and also gives the negative impacts to the environment. According to the Government of Alberta Employment and Immigration. (2009), the exposure to the wood dust can cause poisonous to the human being, lead to eyes, nose and throat irritation, dermatitis, respiratory system effects and the most dangerous effects is it can caused cancer that will lead to death. Besides, it will also lead to pollution of the environment. Research from the Environmental and Public Health Issue. (2011) shows that by-products of the lumber industry which produced the waste wood or sawdust can cause environmental problems may include air emissions, liquid effluent and solid wastes.

However, all the safety, health and environmental issues of the sawdust can be overcome by having a good and proper treatment to the sawdust released in the industry and by using a suitable Personal Protective Equipment (PPE) when exposed to the sawdust. Plus, sawdust actually can be used as the alternative to replace wood in several industries.

Economical disposal of sawdust is a problem of growing concern to the wood industries as enormous quantities of sawdust are produced annually by sawmills. Actually, sawdust has many uses than can replace wood itself. The uses of sawdust can generally be divided into four main purposes (Goddoy, Aguirre, & Diaz, n.d.):

i. Wood cellulose (lignocellulose) products: energy, bio-fertilizers, food supplements;
ii. Bioactive substances and natural forest products: wax, chlorophyll derivatives, essential oils, feed-meal;
iii. Resins and their derivatives: colophony (rosin), turpentine;
iv. Furniture and panels: furniture, particleboard.

Sawdust is widely used in the production of fiberboard or particleboards that for the manufacturing of the furniture core stock, floor underlayment, door cores, cores for kitchen cabinet tops, and wall paneling. Nowadays, sawdust bonded with new and improved resins or known as polymers which are not just used in building and automotive but also involved for packaging, for the preparation of various household articles, furniture, office appliances and other items (Mun'aim, Hamdan, Rahman, & Islam, 2011).

2.2 Low Density Polyethylene (LDPE)

Since World War II, plastics, fibers, elastomers, rubbers, proteins, and cellulose have permeated the world in every way and fulfill a variety of applications. Polymers may be the main ingredient, or even additives which play a crucial role in properties of the final material, such as in asphalt, shampoo and many more which make the demand for the polymer itself had been increases. Polymer is a large molecule, or macromolecule, composed of many repeated subunits, known as monomers. In 1922, Hermann Staudinger stating that natural rubbers were made up of long repetitive chains of monomers that gave rubber its elasticity which known as polymer (Bellis, 2014). The first "synthetic" polymers used were really just modified natural polymers, such as nitrated cellulose.

In 1933, low density polyethylene was found by Imperial Chemical Industries. From eHoww (n.d.), polyethylene was first commercialized during the World War II as it was being used as insulation on radar cables. Low density polyethylene is the first polyolefin that was originally prepared about fifty years ago by the high pressure polymerization of ethylene. It has the chemical formula of $(C2H4)nH2$. Figure 2 shows the chemical structure of the low density polyethylene.

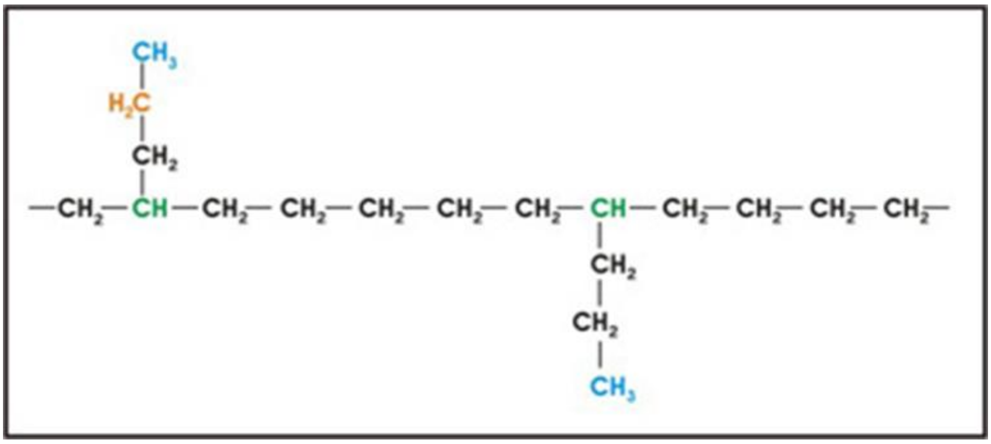

Figure 2: Chemical structure for low density polyethylene (LDPE)

It has low density and only a small amount of branching. Low density polyethylene is defined by a density range of 0.910–0.940 g/cm3. Low density polyethylene has weak intermolecular forces as the instantaneous-dipole induced-dipole attraction is less which results in a lower tensile strength and increased ductility. It is very flexible, easy to clean. According to Dynalab Corp. (n.d.), low density polyethylene is usually used plastic especially in dispensing bottles or wash bottles and widely used to make plastic items that need to be molded, such as plastic bottles used in labs and some prostheses. Nowadays, it is widely used in the polymer composites such as in the wood polymer composites (WPCs) which low density polyethylene acts as the polymer that enhance the properties of the composites.

Even though low density polyethylene are widely used and have a lot of benefits towards the current development, there are still health and environmental issues regarding the increment of the uses of low density polyethylene day by day. For example, eye contact with low density polyethylene resins or dust may cause irritation or corneal injury due to mechanical action while vapor from the heated resin may cause mild discomfort and redness of the eyes. Research from The Dwo Company

(2009), prolonged skin contact is essentially nonirritating but these materials are often processed as molten polymers at elevated temperatures and it may cause burns to the skin. Low density polyethylene is non-toxic non hazards material and can be considered as material safe for contact with humans and animals, and it just caused a low acute toxicity while it dusts and vapors or fumes evolved during thermal processing may cause irritation to the respiratory system. Low density polyethylene is a non-reactive product and inert at storage conditions. From Reliance Industry (n.d.), low density polyethylene is insoluble in water and non-biodegrable, so it can cause pollution to the environment.

2.3 Low Density Polyethylene (LDPE) Sawdust Composites

In the early 1990s, the wood plastic composites (WPCs) had been introduced. Wood-plastic composites (WPCs) are composite materials made of wood fiber or wood flour and thermoplastics. It was known as the new generation of materials for house ware, automobiles, construction and many more (Kamel, Adel, El-Sakhawy, & Nagieb, 2007). Figure 3 shows the WOOD plastic composite product.

Figure 3: Wood plastic composite

In the wood industry, a huge amount of wood waste known as sawdust or wood flour is generated at different stages of the wood processing and it was disposed of in landfills or burned. The wood wastes can be reused by the addition of recycled plastics renders that not just can enhance the mechanical properties of the composites but it also help to reduce the environmental problems (Atuanya, Ibhadode, & Igboanugo, 2011).

Nowadays, plastics are widely been used in a number of application which can potentially be recovered for recycling. The large volume and the low cost of this material promising that a continue source for raw materials for the development of thermoplastic composites with natural fibers (Kamel, Adel, El-Sakhawy, & Nagieb, 2007).

The introduction of the development in the WPCs and it wastes starting in 1970s, by newly developed synthetic fillers because of better performance (Rahman, Islam, Rahman, Hannan, Dungani, & Khalil, 2013). Several studies had been conducted to test on the effects of the chemical treatment with the polymer as such the low density polyethylene itself to the mechanical strength and properties of the composites compared with raw wood or sawdust.

Recently, the production of composites using natural substances as reinforcing fillers for thermoplastics, which melt at relatively low temperatures, such as polyethylene and polystyrene had become popular. This is due to their abundant availability, low cost, and renewable nature. It enhance the properties of the composites in resulting the high specific strength and stiffness, low hardness which minimizes the abrasion of equipment during processing, relatively low density, biodegradability, and low cost on a unit volume basis (Kamel, Adel, El-Sakhawy, & Nagieb, 2007).

CHAPTER 3

METHODOLOGY

3.1 Research Methodology and Project Activities

The methodology for conducting this research project is exploration and discovery. As this project is mainly an empirical research, the results obtained from this research can be used to compare with other literature results. Besides, the result obtained from this research using different mechanical testing of the sawdust polymer composites can be used as a basis of comparison with other researches done. The results can hence further enhance the research and development on the properties of the sawdust polymer composites. The project activities in this research are mainly experimental work.

Sawdust was purchased from a local sawmill industry, Sun Nsm Lee Sawmill Sdn. Bhd. located in Kampar, Perak and stored in polyethylene bag until needed. Sawdust particle size was analysed using sieve analysis with a series of sieves sizes: 2.36mm, 2.00mm, 1.18mm, 0.60mm, 0.425mm, 0.30mm, 0.212mm, 0.15mm, 0.063mm and pan. Four main and suitable size of the sawdust particles are being chosen to proceed with the experiment. After being sieved, the sawdust need to be mold and chemically treated with low density polyethylene (LDPE), and then it will undergoes several testing to compare the mechanical properties between the pure sawdust and also the low density polyethylene (LDPE) sawdust composite.

3.2 Experimental Procedures/Approach

The figure below shows the general experimental procedures that will be implemented in this research project.

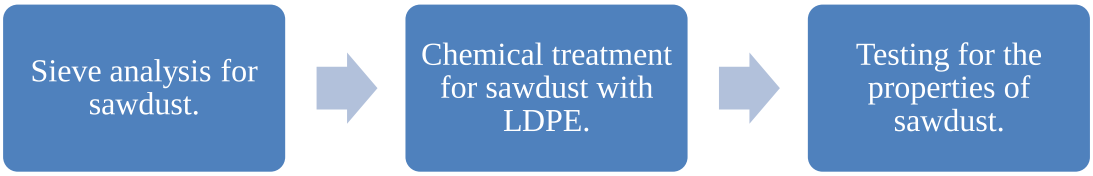

Figure 4: The schematic diagram depicting the general approach in this project.

3.2.1 Experiments and Equipment Needed

Table 1 below shows the experiments and equipment needed during this study.

Table 1: Type of experiments and equipment needed.

Experiments	**Equipment**
Micro Structural Analysis - Surface structure - Adhesion - Structural stability	• Scanning Electron Microscopy (SEM)
Mechanical Testing - Tensile Test - Flexural Test - Hardness Test	• Tensile Machine • Hardness Testing Machine
Dimensional Stability - Water absorption - Thickness swelling	• Weighing
Density	

3.3 Key Milestones

Several key milestones for this research project must be achieved in order to meet the objective of this project:

Problem Statement and Objective of the project

Identifying the purpose of this research project

Literature Review

Gathering as much information as possible from various sources such as journals and websites

Experiment Design

Identifying the subjects that need to be investigated and the experimental procedures, as well as the chemicals needed and the collection of results

Data Analysis and Interpretation

The findings obtained are analyzed and interpreted critically. Comparison with other literature readings will also be done.

Documentation and Reporting

The whole research project will be documented and reported in detail. Recommendations or aspects that can be further improved in the future will also be discussed.

3.4 Gantt Chart

Table 2 and 3 below shows the gantt chart that need to be followed during this study for FYP I and FYP II respectively.

Table 2: Gantt chart for FYP I

NO	DETAIL / WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Title														
2	Preliminary Research Work and Literature Review														
3	Submission of Extended Proposal Defence							●							
4	Oral Proposal Defence Presentation														
5	Buy the sawdust														
6	Experimental Work: Sieving Sawdust														
7	Confirmation of Polymer Availability														
8	Experimental Work: Water Absorption of Sawdust With Different Particles Size														
9	Submission of Interim Final Report														●

Table 3 : Gantt chart for FYP II

NO	DETAIL / WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Sample preparation															
2	Water absorption test															
3	Density determination															
4	Thickness swelling determination															
5	Flexural test															
6	SEM characterisation															
7	Submission of Progress Report								●							
8	Pre-EDX											●				
9	Submission of Draft Report												●			
10	Submission of Dissertation													●		
11	Submission of Technical Paper													●		
12	Oral presentation														●	
13	Submission of Project Dissertation															●

3.5 Experiment Conducted

3.5.1 Sieve Analysis

3.5.1.1 Materials and Apparatus

1. Sawdust
2. Sieving machine

3.5.1.2 Procedure

1. Put the sawdust on the first part of the sieving machine.
2. Put the sieving tray on the machine and switch on the machine.
3. Set the time until 10 minutes.
4. Sieve the sawdust for the second time.
5. Separate the sawdust according to the particle size. Only four sizes will be chosen in this experiment which is 0.063, 0.212, 0.425 and 1.18 mm.

3.5.2 Water Absorption for Raw Sawdust

3.5.2.1 Materials and Apparatus

1. Beaker
2. Weighing balance
3. Oven
4. Distilled water
5. Sawdust

3.5.2.2 Procedure

1. Weigh 10g of sawdust according to the size.
2. Put the sawdust in the oven for one day to remove all the moisture content between the sawdust.
3. Weigh the sawdust until the constant weight is obtained.
4. Pour 65ml of distilled water into the four beakers containing the sawdust and left it for two hours at room temperature. Make sure all the sawdust immersed in the water.
5. After two hours, filter the sawdust.
6. Weigh the sawdust again.
7. Finally, calculate the percentage of weight gained by the sawdust according to the particle size.

3.5.3 Sample Preparation

3.5.3.1 Materials and Apparatus

1. Compression molding machine
2. Different types of mold
3. Sawdust
4. Low density polyethylene (LDPE)

3.5.3.2 Procedure

1. Prepare the sample for every test by using different weight according to the mold.
2. Put the mixture of sawdust and LDPE in the different mold for water absorption, tensile strength test and flexural test.
3. Refer the table below for the composition of different types of mold.

For water absorption

Table 4: Water absorption for ratio of 60:40

Sample	Ratio of LDPE(g):sawdust(g)	Percentage %LDPE:%sawdust	Total weight (g)
A	2.4:1.6	60:40	4.0
B	2.4:1.6	60:40	4.0
C	2.4:1.6	60:40	4.0
D	2.4:1.6	60:40	4.0

Table 5: Water absorption for ratio of 75:25

Sample	Ratio of LDPE(g):sawdust(g)	Percentage %LDPE:%sawdust	Total weight (g)
A	3.0:1.0	75:25	4.0
B	3.0:1.0	75:25	4.0
C	3.0:1.0	75:25	4.0
D	3.0:1.0	75:25	4.0

Table 6: Water absorption for ratio of 90:10

Sample	Ratio of LDPE(g):sawdust(g)	Percentage %LDPE:%sawdust	Total weight (g)
A	3.6:0.4	90:10	4.0
B	3.6:0.4	90:10	4.0
C	3.6:0.4	90:10	4.0
D	3.6:0.4	90:10	4.0

For tensile strength test

Table 7: Tensile strength test for ratio of 60:40

Sample	Ratio of LDPE(g):sawdust(g)	Percentage %LDPE:%sawdust	Total weight (g)
A	7.2:4.8	60:40	12.0
B	7.2:4.8	60:40	12.0
C	7.2:4.8	60:40	12.0
D	7.2:4.8	60:40	12.0

Table 8: Tensile strength test for ratio of 75:25

Sample	Ratio of LDPE(g):sawdust(g)	Percentage %LDPE:%sawdust	Total weight (g)
A	9.0:3.0	75:25	12.0
B	9.0:3.0	75:25	12.0
C	9.0:3.0	75:25	12.0
D	9.0:3.0	75:25	12.0

Table 9: Tensile strength test for ratio of 90:10

Sample	Ratio of LDPE(g):sawdust(g)	Percentage %LDPE:%sawdust	Total weight (g)
A	10.8:1.2	90:10	12.0
B	10.8:1.2	90:10	12.0
C	10.8:1.2	90:10	12.0
D	10.8:1.2	90:10	12.0

For flexural test

Table 10: Flexural test for ratio of 60:40

Sample	Ratio of LDPE(g):sawdust(g)	Percentage %LDPE:%sawdust	Total weight (g)
A	4.8:3.2	60:40	8.0
B	4.8:3.2	60:40	8.0
C	4.8:3.2	60:40	8.0
D	4.8:3.2	60:40	8.0

Table 11: Flexural test for ratio of 75:25

Sample	Ratio of LDPE(g):sawdust(g)	Percentage %LDPE:%sawdust	Total weight (g)
A	6.0:2.0	75:25	8.0
B	6.0:2.0	75:25	8.0
C	6.0:2.0	75:25	8.0
D	6.0:2.0	75:25	8.0

Table 12: Flexural test for ratio of 60:40

Sample	Ratio of LDPE(g):sawdust(g)	Percentage %LDPE:%sawdust	Total weight (g)
A	7.2:0.8	90:10	8.0
B	7.2:0.8	90:10	8.0
C	7.2:0.8	90:10	8.0
D	7.2:0.8	90:10	8.0

4. Mold all the samples in the compression molding machine at 170^0C and pressure of 5Mpa for 5 minutes (Kamel, Adel, El-Sakhawy, & Nagieb, 2007).

3.5.4 Water Absorption Test

3.5.4.1 Materials and Apparatus

1. Beaker
2. Weighing balance
3. Oven
4. Distilled water
5. Samples A, B, C, D for different composition

3.5.4.2 Procedure

This test was conducted according to the ASTM D570-99 (2002) (Sultana, Nur, Saha, & Saha, 2012).

1. Prepare small pieces of LDPE sawdust composites with different sawdust size and different sawdust composition.

2. Dry all the composites in the oven for 3 hours at 105^0C.

3. Then, weigh all the composites immediately to get the initial weight, w_0 each sample.

4. Immersed all the samples in the beaker containing 50mL of water each for 24 hours.

5. After 24 hours, weigh the sample again to get the final weigh, w_f after being immersed and measure the volume of water displaced.

6. Finally, calculate the percentage of weight gained to determine the percentage of water absorption according to the sawdust size and composition in every sample.

3.5.5 Density Determination

3.5.5.1 Materials and Apparatus

1. Weighing balance
2. 50 mL beakers
3. Samples A, B, C, D for different composition

3.5.5.2 Procedure

1. All the weight of the samples can be obtained from the data of the initial weight for the water absorption test.

2. Record the volume of water displaced for each sample during the water absorption test.

3. Calculate the density by using the given formula.

3.5.6 Thickness Swelling Determination

3.5.6.1 Materials and Apparatus

1. Vernier caliper
2. Samples A, B, C, D for different composition

3.5.6.2 Procedure

1. Take the initial thickness, T_0 of the samples before being immersed in water during the water absorption test.
2. After the sample immersed in water for 24 hours, take the final thickness of the samples, T_f.
3. Calculate the percentage of thickness swelling by using the formula given.

3.5.7 Tensile Strength Test

3.5.7.1 Materials and Apparatus

1. Machine
2. Samples A, B, C, D for different composition

3.5.7.2 Procedure

This test was conducted according to the ASTM D 638-89 (2002) (Sultana, Nur, Saha, & Saha, 2012).

1. Load the specimen into tensile grips.
2. Attach the extensometer to the sample.
3. Begin the test by separating the tensile grips at a constant rate of 50.00mm/min.
4. End the test after sample break (rupture).

3.5.8 Flexural Test

3.5.8.1 Materials and Apparatus

1. Machine
2. Samples A, B, C, D for different composition

3.5.8.2 Procedure

This test was conducted according to the ASTM D 790-00 (2002) (Sultana, Nur, Saha, & Saha, 2012).

1. Load the specimen into flexural grips.
2. Attach the extensometer to the sample.
3. Begin the test with a constant rate of 2.00mm/min.
4. End the test after sample break (rupture).

3.5.9 Scanning Electron Microscopy (SEM)

3.5.9.1 Materials and Apparatus

1. SEM machine
2. Samples A, B, D for 75:25 composition and samples C with 60:40, 75:25 and 90:10 compositions.

3.5.9.2 Procedure

1. Coated the fractured pieces of samples from the flexural test with a thin layer of gold.
2. Examine each sample by using a scanning electron microscopy.
3. The photographs are presented in the results and discussion section.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Sieve Analysis

4.1.1 Result

Table 10 below is the range of sawdust particle size according to sieve size.

Table 13: Range of sawdust particles size according to sieve size.

Sample	**Range of sawdust particles size (mm)**
A	$0.063 \leq x \leq 0.149$
B	$0.212 \leq x \leq 0.299$
C	$0.425 \leq x \leq 0.599$
D	$1.18 \leq x \leq 1.99$

4.1.2 Discussion

From the data obtained in Table 10, it shows that the different size of the mesh will sieve the different size of sawdust particles. The size of the sawdust particles decreases as the mesh size increases.

4.2 Water Absorption for Raw Sawdust

4.2.1 Result

The following formula is used to calculate the percentage of water absorption by the sawdust (Kamel, Adel, El-Sakhawy, & Nagieb, 2007):

$$\boldsymbol{PWG = \frac{W_f - W_0}{W_0} \times 100\%}$$

Where

PWG = Percentage of weight gained

w_f = Weight of sawdust after immersed in water

w_0 = Weight of sawdust before immersed in water

Table 14: Percentage of weight gained according to the range of sawdust particles size.

Sample	**Weight of beaker (g)**	**Weight of sawdust before immersed in water, w_0 (g)**	**Weight of sawdust after immersed in water, w_f (g)**	**Percentage of weight gained, PWG (%)**
A	116.61	8.95	40.64	354.07
B	109.79	8.86	37.68	325.28
C	102.53	8.96	36.64	308.92
D	117.73	9.47	18.57	96.09

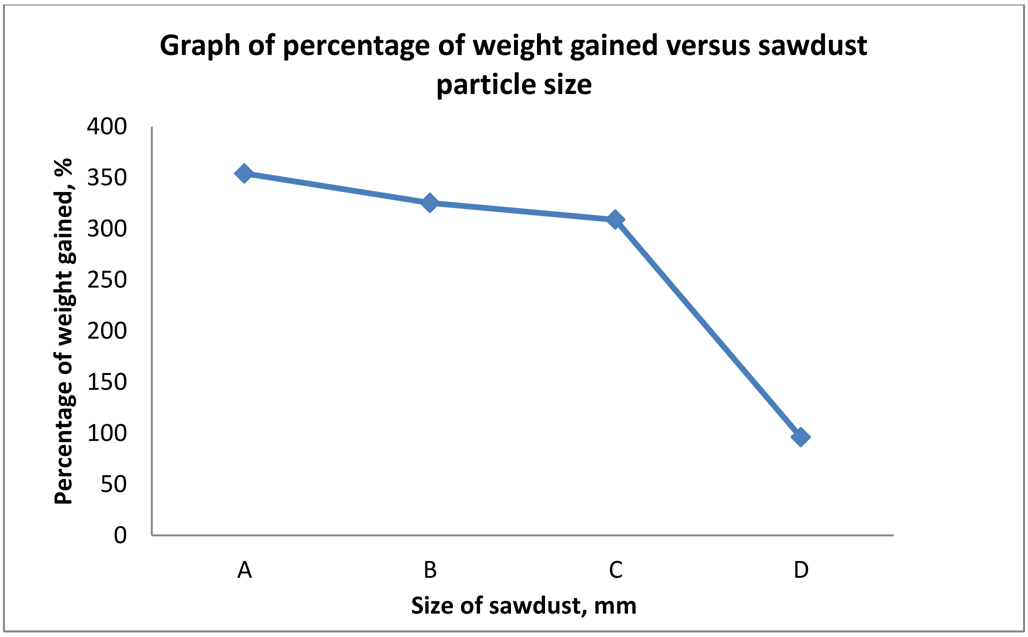

Figure 5: Graph of percentage of weight gained versus size of sawdust particles.

4.2.2 Discussion

From the graph of Figure 5 shown in the result part, it shows that the amount of water being absorbed by the sawdust decreases with the increase in the particle size. This is due to the smaller size of the particles from group A that are $0.063 \leq x \leq 0.149$ mm will increase the surface area for water absorption as compared with the range of particles size in group B, C and D.

4.3 Water Absorption Test

4.3.1 Result

The following formula is used to calculate the percentage of water absorption by the sawdust (Kamel, Adel, El-Sakhawy, & Nagieb, 2007):

$$\boldsymbol{PWG = \frac{W_f - W_0}{W_0} \times 100\%}$$

Where

PWG = Percentage of weight gained

w_f = Weight of sawdust after immersed in water

w_0 = Weight of sawdust before immersed in water

Table 15: Percentage of weight gained for composite of LDPE:sawdust, 60:40

LDPE sawdust composite	Initial weight, W_0 (g)	Final weight, W_f (g)	Percentage of weight gained, PWG (%)
A	2.53	2.64	4.53
B	2.55	2.65	4.00
C	2.55	2.64	3.47
D	2.62	2.78	5.23

Table 16: Percentage of weight gained for composite of LDPE:sawdust, 75:25

LDPE sawdust composite	Initial weight, W_0 (g)	Final weight, W_f (g)	Percentage of weight gained, PWG (%)
A	2.57	2.68	4.28
B	2.54	2.63	3.54
C	2.88	2.62	2.51
D	2.49	2.63	5.39

Table 17: Percentage of weight gained for composite of LDPE:sawdust, 90:10

LDPE sawdust composite	Initial weight, W_0 (g)	Final weight, W_f (g)	Percentage of weight gained, PWG (%)
A	2.43	2.53	4.18
B	2.54	2.62	3.19
C	2.58	2.64	2.18
D	2.50	2.58	3.28

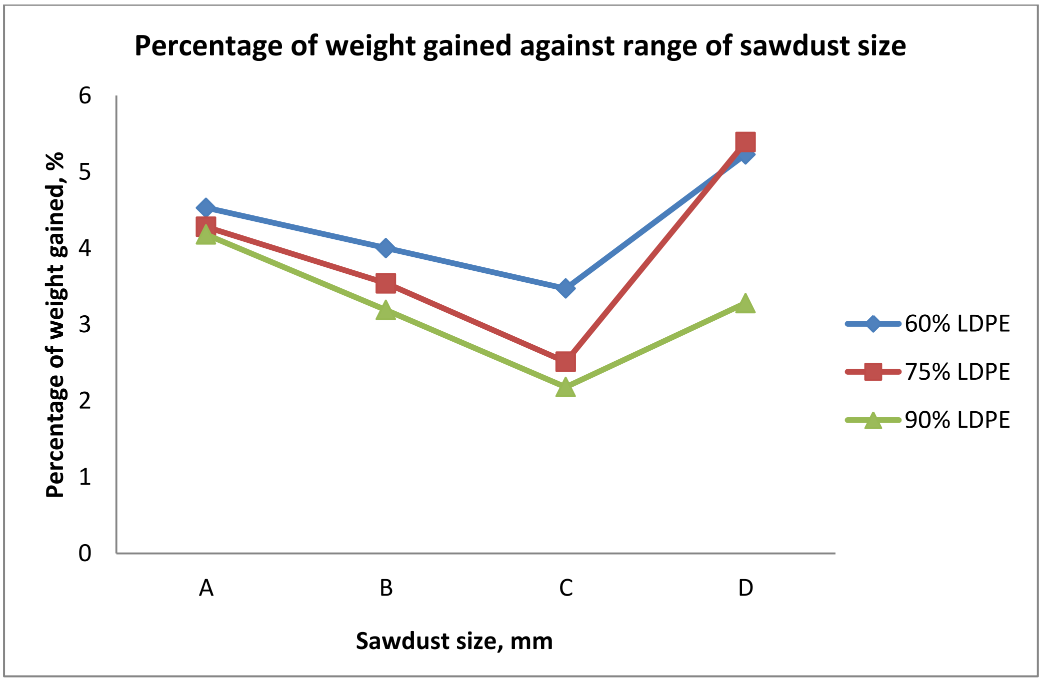

Figure 6: Graph of percentage of weight gained against range of sawdust size

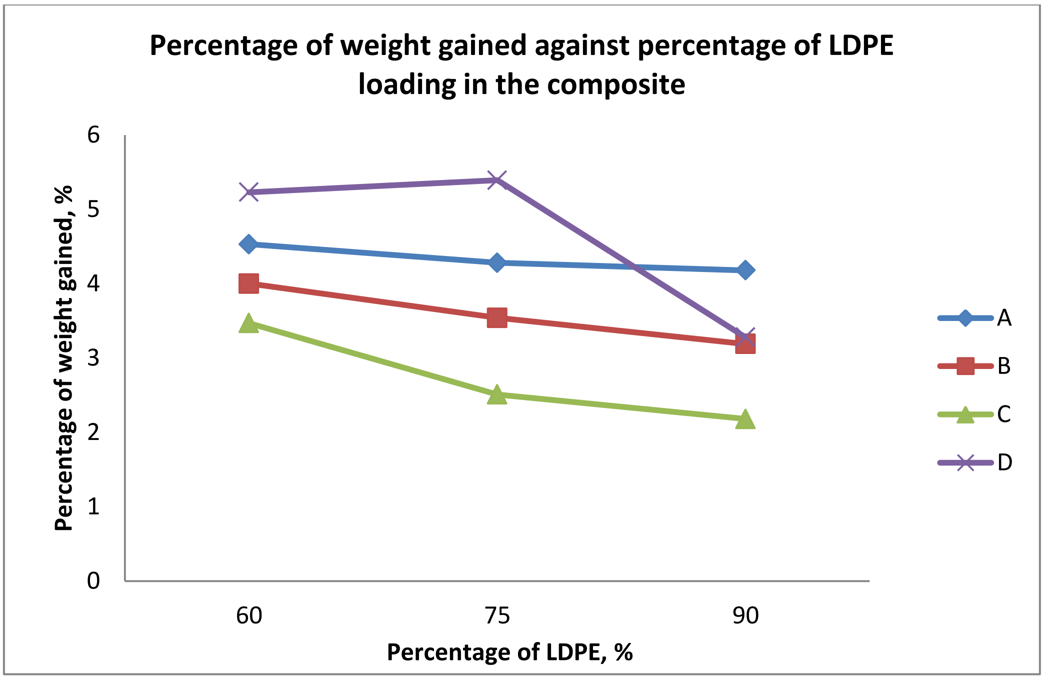

Figure 7: Graph of percentage of weight gained against percentage of LDPE loading in the composite

2.3.2 Discussion

From Figure 6, the graph shows that as the range of sawdust size increases, the amount of water being absorbed by the sample increases for all the three different composite loading. We can see that all the graph trending shows the decrement. This is because as the size of sawdust particles in the sample increases, it will reduce the surface area for water absorption as compared to small range of sawdust particle size. The smaller size of the particles from sample A that are $0.063 \leq x \leq 0.149$ mm provide more moisture sorption due to the increase in surface area and inter–particle friction leading to smaller flow rates of the particles as compared to samples B and C (Shehu, Aponbiede, Ause, & Obiodunukwe, 2013). However, the water absorption for sample D with the range of sawdust particles of $1.18 \leq x \leq 1.99$ mm for all composition suddenly increase in the percentage of the weight gained for 60:40, 75:25 and 90:10 composite loading which are 5.23%, 5.39% and 3.28% respectively. This is due to the increase in particle size will decreases homogeneity of sawdust composite, and decreases material coverage in some parts of matrix thus particles have many possibility to contact water (Dorostkar, Rafighi, & Madhoushi, 2014). The other reason is that we can observed that the void areas or pore sizes for the biggest sawdust particles in the composites can be seen clearly compared to the others (Charoenwong, & Pisuchpen, n.d.). Besides, the surrounding temperature also might be affected on the result of water absorption for sample D.

Other than that, from the Figure 7, the graph shows that as we increases the amount of sawdust in the composite, the water absorption will also increase. From the graph we can see that the loading with 60:40 ratio of LDPE:sawdust shows the highest percentage of weight gained for sample A, B, C and D which are 4.53%, 4.00%, 3.47% and 5.23% respectively. This is based on the properties of the sawdust itself that will absorb water as compared to LDPE. This is aligned with one of the research shows that as the sawdust ratio increases, it will increase the area for water absorption to take place as compared to the sample with smaller ratio of sawdust (Kamel, Adel, El-Sakhawy, & Nagieb, 2007).

4.4 Density Determination

4.4.1 Result

The following formula is used to calculate the density of every sample:

$$Density, \rho = \frac{Mass\ of\ composite\ polymer}{Volume\ of\ water\ displace}$$

Table 18: Density of composite LDPE:sawdust, 60:40

Sample	Initial volume of water in the beaker, v_0 (mL)	Final volume of water in the beaker, v_f (mL)	Initial weight of composite polymer, w_0 (g)	Density, ρ (kg/m^3)
A	50.0	54.8	2.53	551.62
B	50.0	54.1	2.55	629.41
C	50.0	53.8	2.55	670.71
D	50.0	53.7	2.62	714.97

Table 19: Density of composite LDPE:sawdust, 75:25

Sample	Initial volume of water in the beaker, v_0 (mL)	Final volume of water in the beaker, v_f (mL)	Initial weight of composite polymer, w_0 (g)	Density, ρ (kg/m^3)
A	50.0	54.7	2.57	541.30
B	50.0	54.1	2.54	621.95
C	50.0	53.9	2.55	651.28
D	50.0	53.5	2.49	713.89

Table 20: Density of composite LDPE:sawdust, 90:10

Sample	Initial volume of water in the beaker, v_0 (mL)	Final volume of water in the beaker, v_f (mL)	Initial weight of composite polymer, w_0 (g)	Density, ρ (kg/m^3)
A	50.0	54.6	2.43	523.89
B	50.0	54.1	2.54	614.59
C	50.0	53.9	2.58	661.45
D	50.0	53.6	2.50	700.90

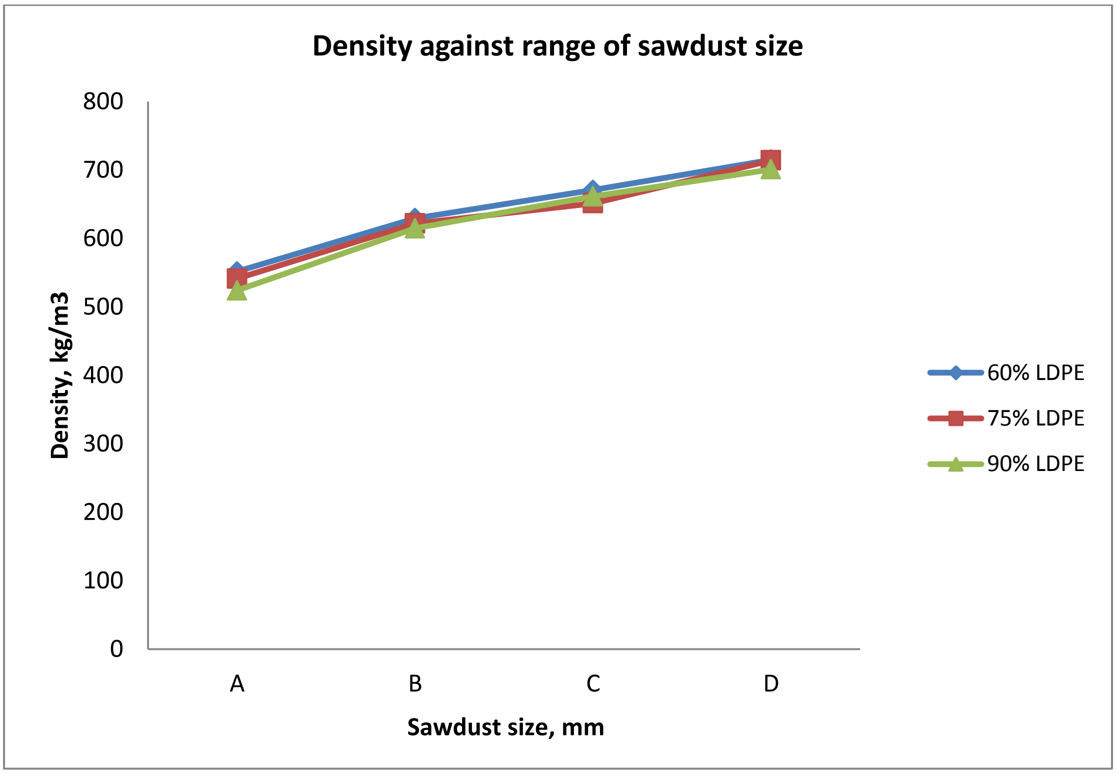

Figure 8: Graph of density of sample against range of sawdust size

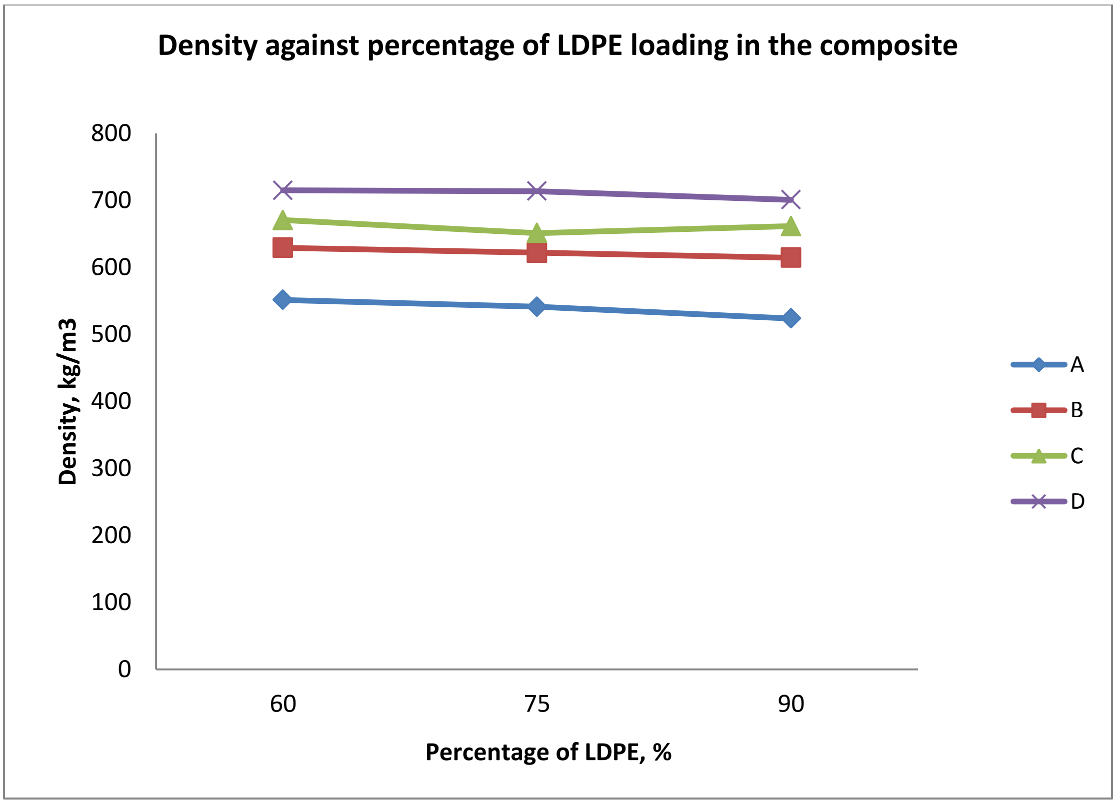

Figure 9: Graph of density of sample against percentage of LDPE loading in the composite

4.4.2 Discussion

Based on the Figure 8, the graph shows that the density of the sample increases with the increase in the sawdust particles size in the composite. The lowest density is for the sample A of every composition with the reading of 551.62, 541.30 and 523.89 kg/m3 respectively while the highest density value for every composition is for sample D with the reading of 714.97, 713.89 and 700.9 kg/m3 respectively. This is due to the fact that for smaller particle sizes, they have higher compressibility because they had more porosity, thus the density will be lower (Shehu, Aponbiede, Ause, & Obiodunukwe, 2013).

For the different composition of composites, the graph in Figure 9 shows that when the amount of LDPE increases, the density also will decrease. For sample A, B, C and D they have higher density when the sawdust particles amount at 40% which are the reading 551.62, 629.41, 670.71 and 714.97 kg/m3 respectively while the lower density reading for every sample is at 10% of sawdust particles amount with the reading of 523.89, 614.59, 661.45 and 700.90 kg/m3 respectively. This is due to the density of the sawdust particles are higher than LDPE that cause when we increase the amount of sawdust the density of the composite will increase. The results shows aligned with one of the study done showing that as the density of the composite increase with the increase in sawdust particles amount due to the higher density of sawdust itself (Idrus, M.A.M.M., Hamdan, S., Rahman, M.R., & Islam, M.S., 2011).

From all the data obtained, we can observed that the density of all the samples are within the range of 500<x<800 kg/m3.

4.5 Thickness Swelling Determination

4.5.1 Result

The following formula is used to calculate the percentage of thickness swelling for every sample:

$$\%\,\textit{Thickness swelling} = \frac{T_f - T_0}{T_0} \times 100\%$$

Table 21: Percentage of thickness swelling for composite LDPE:sawdust, 60:40

LDPE sawdust composite	**Initial thickness, T_0 (cm)**	**Final thickness, T_f (cm)**	**Percentage of thickness swelling (%)**
A	0.41	0.46	12.57
B	0.36	0.39	9.00
C	0.37	0.40	8.20
D	0.38	0.41	7.23

Table 22: Percentage of thickness swelling for composite LDPE:sawdust, 75:25

LDPE sawdust composite	**Initial thickness, T_0 (cm)**	**Final thickness, T_f (cm)**	**Percentage of thickness swelling (%)**
A	0.35	0.39	11.54
B	0.39	0.43	8.93
C	0.39	0.41	6.50
D	0.40	0.43	7.13

Table 23: Percentage of thickness swelling for composite LDPE:sawdust, 90:10

LDPE sawdust composite	**Initial thickness, T_0 (cm)**	**Final thickness, T_f (cm)**	**Percentage of thickness swelling (%)**
A	0.42	0.46	9.81
B	0.42	0.45	7.32
C	0.39	0.41	6.34
D	0.43	0.46	6.12

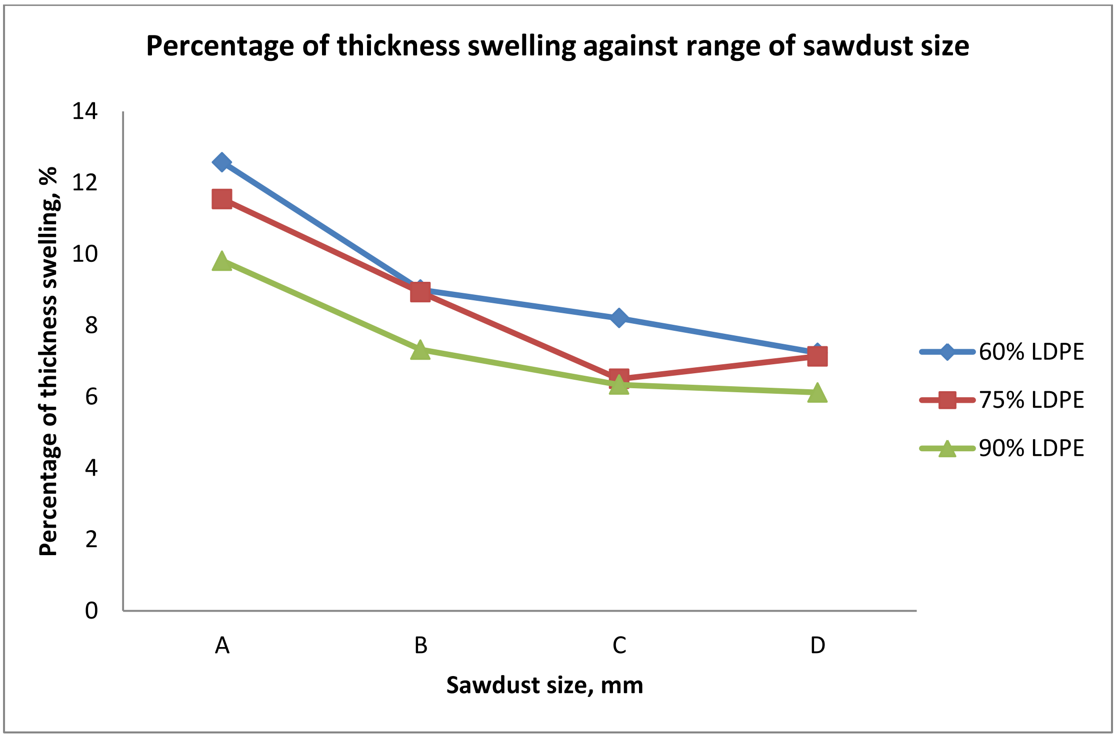

Figure 10: Graph of percentage of thickness swelling against range of sawdust size

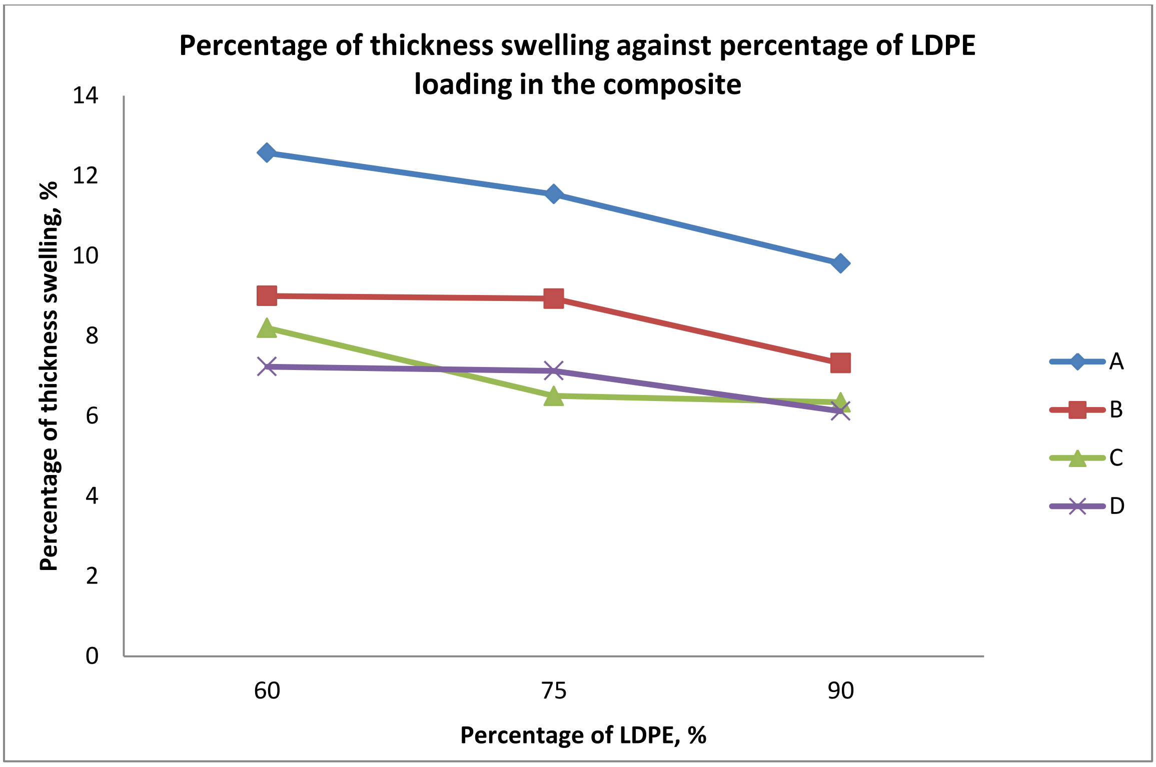

Figure 11: Graph of percentage of thickness swelling against percentage of LDPE loading in the composite

4.5.2 Discussion

From the graph shown in Figure 10, it shows that the percentage of thickness swelling decreases as the sawdust particles size of the composite increases. This is because it is related to the amount of water being absorbed by the sample with smaller sawdust particles size is more compare to the others due to the reason of surface area for water absorption. From the data collected, we can see that sample A for all composition have the highest percentage of thickness swelling with the percentage of 12.57, 11.54, and 9.81% respectively followed by sample B, C and D. The reason is because the large particles size are tightly interlocked and randomly oriented in three dimensions which increase their strength as compared to the small particles (Charoenwong, & Pisuchpen, n.d.).

For the different ratio of sawdust and LDPE, as we increases the amount of sawdust in the composite, the percentage of thickness swelling will increase. From the graph in Figure 11 shows that all the samples with 60:40 ratio LDPE:sawdust have the highest percentage of thickness swelling with the reading of 12.57, 9.00, 8.20 and 7.23% for sample A, B, C and D respectively. This is because as we increase the amount of sawdust in the composite, it will provide more surface area of water absorption as compared to the increase in the amount of LDPE. When the water absorption increases, it will have the higher tendency for the increase in the percentage of thickness swelling. The same result also had been investigated from the previous study shows the percentage of thickness swelling will decrease with the increase in the amount of the sawdust in the composite (Medupin, R. O., Abubakre, O. K., Ukoba, K. O., & Imoisili, P. E., 2013).

From both of the graph it shows that sample A with the smaller range of sawdust particles size and with the composition ratio of 60:40, LDPE:sawdust shows the highest percentage of thickness swelling while the sample D with the largest range of sawdust particles size and with the composition of 90:10, LDPE:sawdust shows the lowest percentage of thickness swelling.

4.6 Tensile Strength Test

4.6.1 Result

Table 24: Tensile strength for composite LDPE:sawdust, 60:40

Sample	**Elongation percentage (%)**	**Tensile strength (N/mm^2)**
A	0.39	2.21
B	0.43	2.67
C	0.47	3.01
D	0.59	3.65

Table 25: Tensile strength for composite LDPE:sawdust, 75:25

Sample	**Elongation percentage (%)**	**Tensile strength (N/mm^2)**
A	0.58	3.31
B	0.60	3.83
C	2.41	4.98
D	1.61	4.35

Table 26: Tensile strength for composite LDPE:sawdust, 90:10

Sample	Elongation percentage (%)	Tensile strength (N/mm^2)
A	1.72	4.87
B	1.77	4.93
C	3.09	5.78
D	2.32	5.12

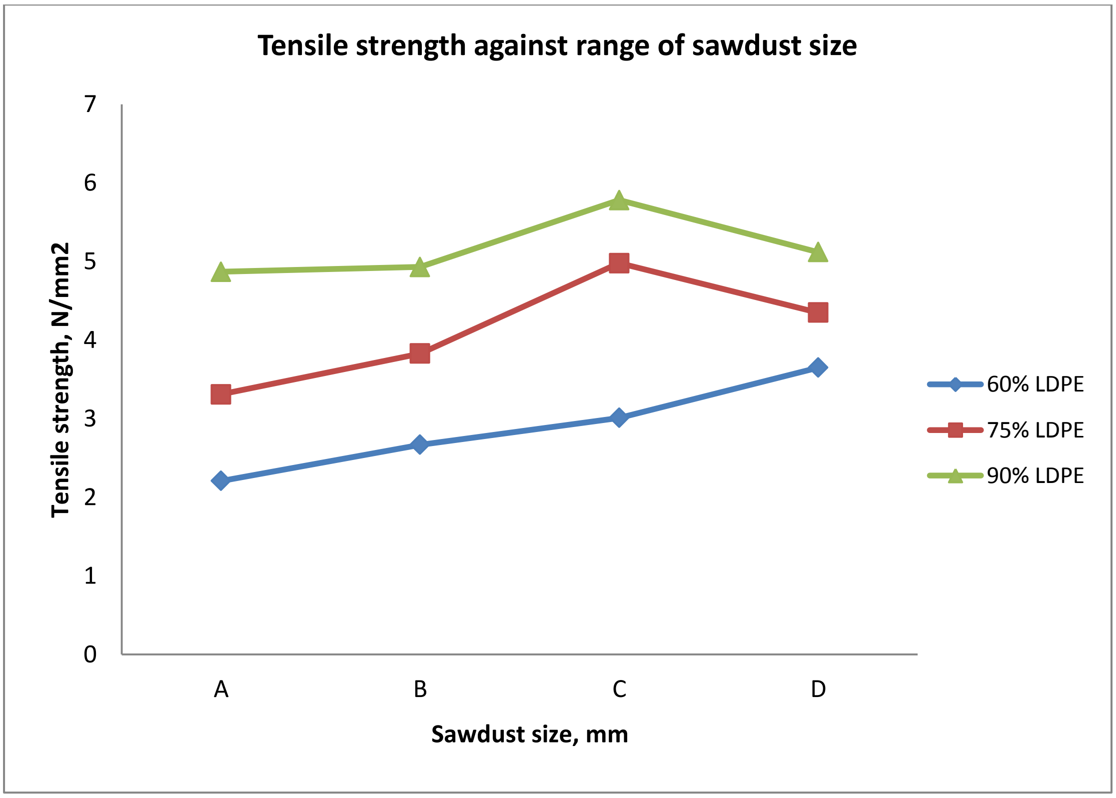

Figure 12: Graph of tensile strength against range of sawdust size

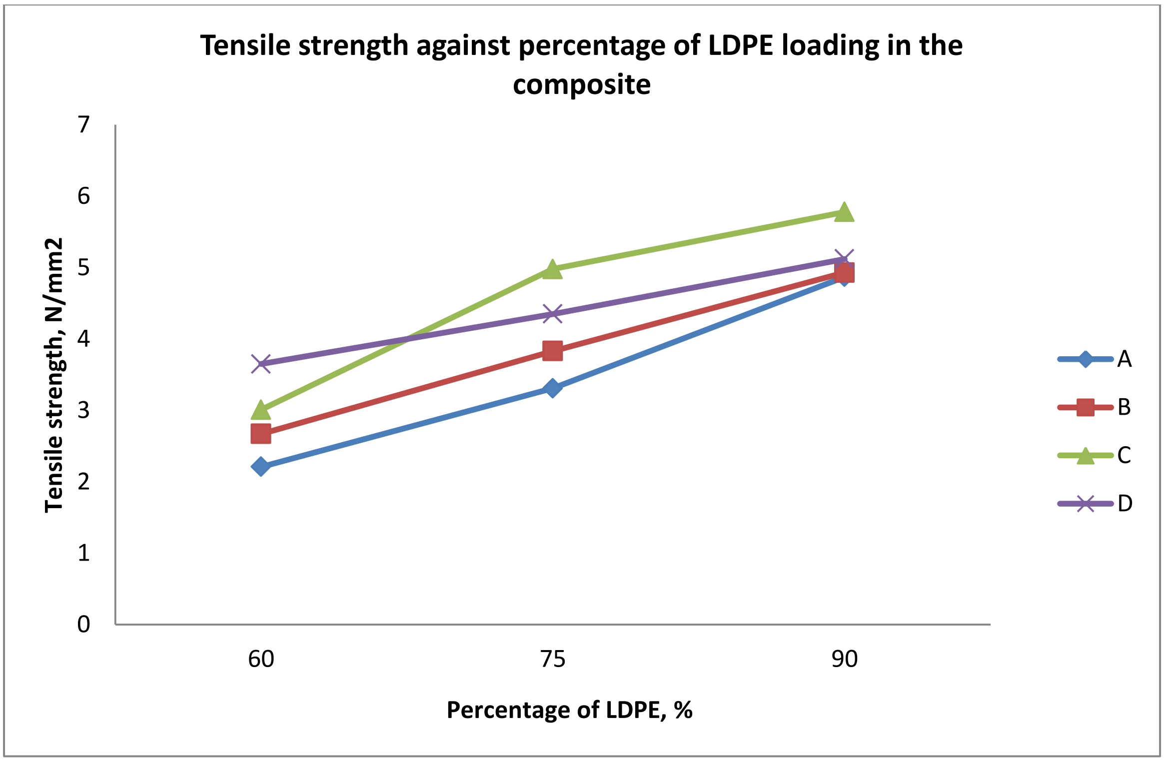

Figure 13: Graph of tensile strength against percentage of LDPE loading in the composite

4.6.2 Discussion

From graph in Figure 12, it shows that the tensile strength will increases with the increases in the range of sawdust particles size used in the sample. This is due to the largest particles provide more surface for the LDPE coverage during the molding process which increase the strength of the samples with larger sawdust particles size. From the data collected, we can see that sample C for all composition have the highest value of tensile strength with 3.01, 4.98, and 5.78 N/mm2 respectively followed by sample D, B and A. However, there are drop in the strength value for sample D as expected since there was a sharp increase in water absorption for that sample (Shehu, Aponbiede, Ause, & Obiodunukwe, 2013).

For the different ratio of sawdust and LDPE, as we increases the amount of LDPE in the composite, the tensile strength will increase. From the graph in Figure 13 shows that all the samples with 90:10 ratio LDPE:sawdust have the highest value of tensile strength with the reading of 4.87, 4.93, 5.78and 5.12 N/mm2 for sample

A, B, C and D respectively. This is because as we increase the amount of LDPE in the composite, it will increase the interfacial strength between the sawdust and LDPE in the composite (Idrus, Hamdan, Rahman, & Islam, 2011). The result obtained was as expected from the previous study shown that the tensile strength will increase with the increase in the range of sawdust particles size used (Kamel, Adel, El-Sakhawy, & Nagieb, 2007).

From both of the graphs it shows that sample A with the smaller range of sawdust particles size and with the composition ratio of 60:40, LDPE:sawdust shows the lowest value of tensile strength while the sample D with the largest range of sawdust particles size and with the composition of 90:10, LDPE:sawdust shows the highest value of tensile strength.

4.7 Flexural Test

4.7.1 Result

Table 27: Flexural strength for composite LDPE:sawdust, 60:40

Sample	Flexural Strength, MPa	Strain, %	Elastic Modulus, MPa
A	6.89	4.59	297.72
B	7.01	4.78	287.65
C	8.96	5.79	259.76
D	8.70	5.65	260.90

Table 28: Flexural strength for composite LDPE:sawdust, 75:25

Sample	Flexural Strength, MPa	Strain, %	Elastic Modulus, MPa
A	7.18	4.83	288.73
B	7.99	5.44	267.89
C	10.88	6.08	248.40
D	10.18	5.69	230.50

Table 29: Flexural strength for composite LDPE:sawdust, 90:10

Sample	Flexural Strength, MPa	Strain, %	Elastic Modulus, MPa
A	8.91	5.54	273.45
B	9.23	6.01	247.89
C	10.98	6.15	228.90
D	10.23	6.10	230.85

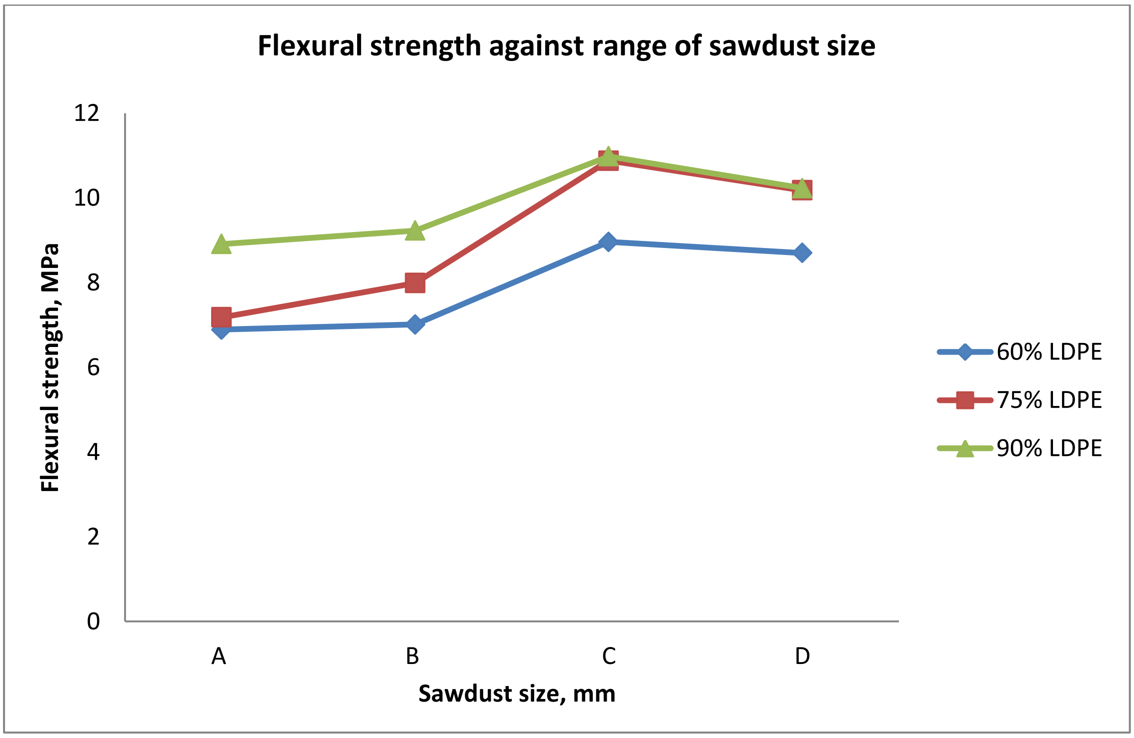

Figure 14: Graph of flexural strength against range of sawdust size

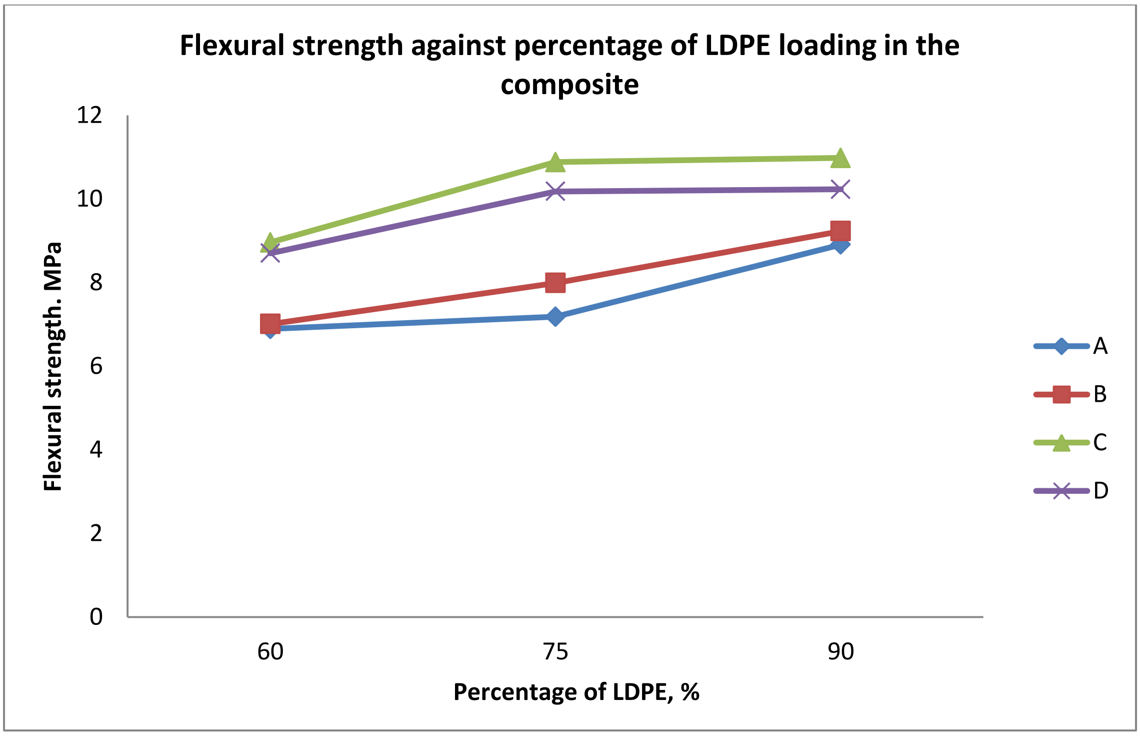

Figure 15: Graph of flexural strength against percentage of LDPE loading in the composite

4.7.2 Discussion

From graph in Figure 14, it shows that the flexural strength will increases with the increases in the range of sawdust particles size used in the sample. This is due to the largest particles provide more surface for the LDPE coverage during the molding process which increase the interfacial bonding between the particles (Sultana, Nura, Sahaa, & Sahab, 2012). From the data collected, we can see that sample C for all composition have the highest value of flexural strength with 8.96, 10.88, and 10.98 Mpa respectively followed by sample D, B and A. However, there are drop in the strength value for sample D as expected since there was a sharp increase in water absorption for that sample (Shehu, Aponbiede, Ause, & Obiodunukwe, 2013).

For the different ratio of sawdust and LDPE, as we increases the amount of LDPE in the composite, the flexural strength will increase. From the graph in Figure 15 shows that all the samples with 90:10 ratio LDPE:sawdust have the highest value of tensile strength with the reading of 8.91, 9.23, 10.98and 10.23 MPa for sample

A, B, C and D respectively. This is because as we increase the amount of LDPE in the composite, it was attributed to the flow and film formation of LDPE in the composite structure, which increased the internal bond strength and increased the composite strength. (Kamel, Adel, El-Sakhawy, & Nagieb, 2007). The result obtained was as expected from the previous study shown that the tensile strength will increase with the increase in the range of sawdust particles size used (Kamel, Adel, El-Sakhawy, & Nagieb, 2007).

From both of the graph it shows that sample A with the smaller range of sawdust particles size and with the composition ratio of 60:40, LDPE:sawdust shows the lowest value of flexural strength while the sample D with the largest range of sawdust particles size and with the composition of 90:10, LDPE:sawdust shows the highest value of flexural strength.

4.8 Scanning Electron Microscopy (SEM)

4.8.1 Result

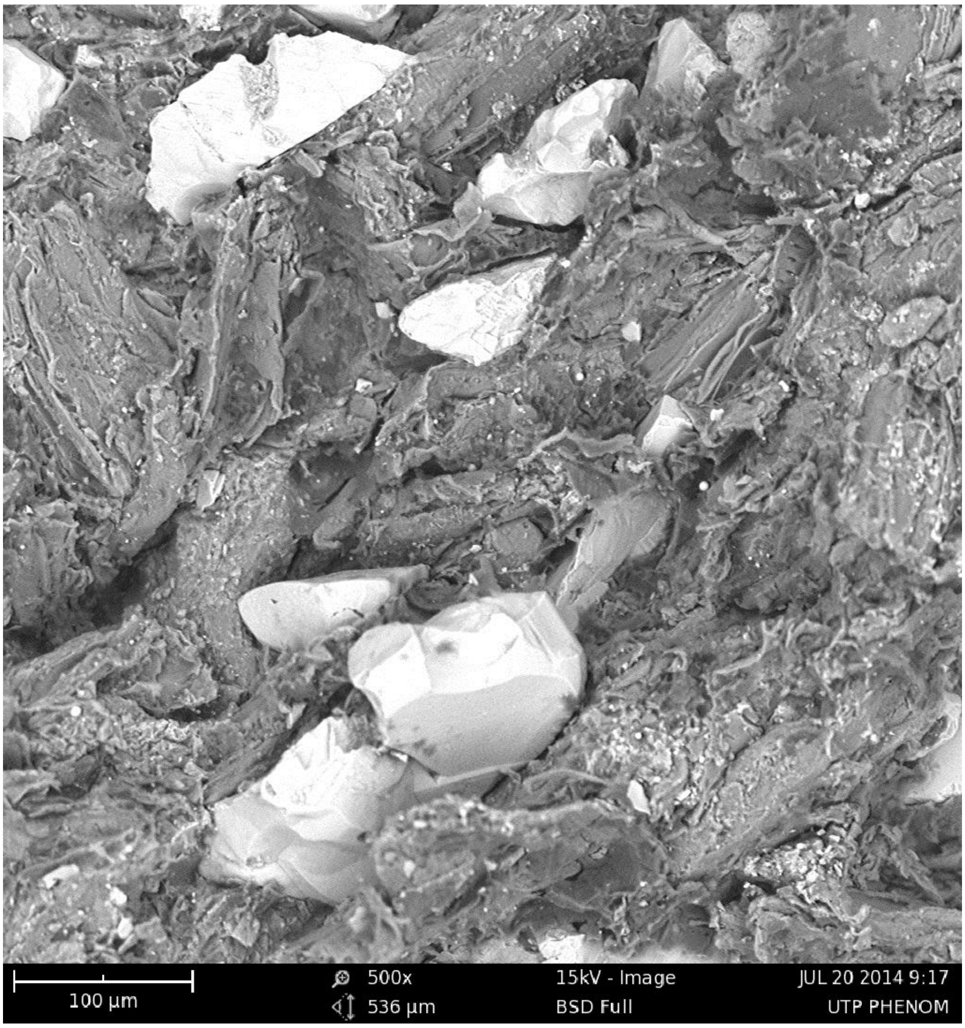

Figure 16: SEM for sample A with composition of 75:25, LDPE:sawdust composite

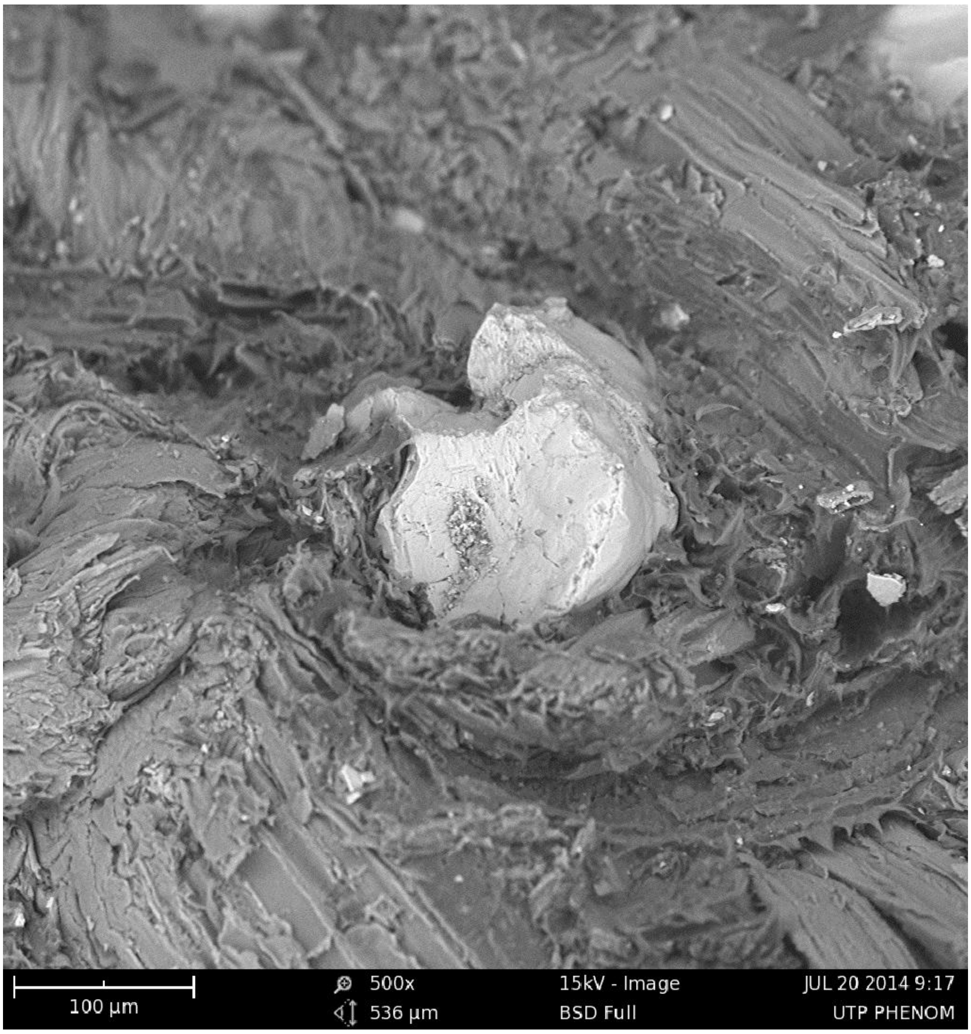

Figure 17: SEM for sample B with composition of 75:25, LDPE:sawdust composite

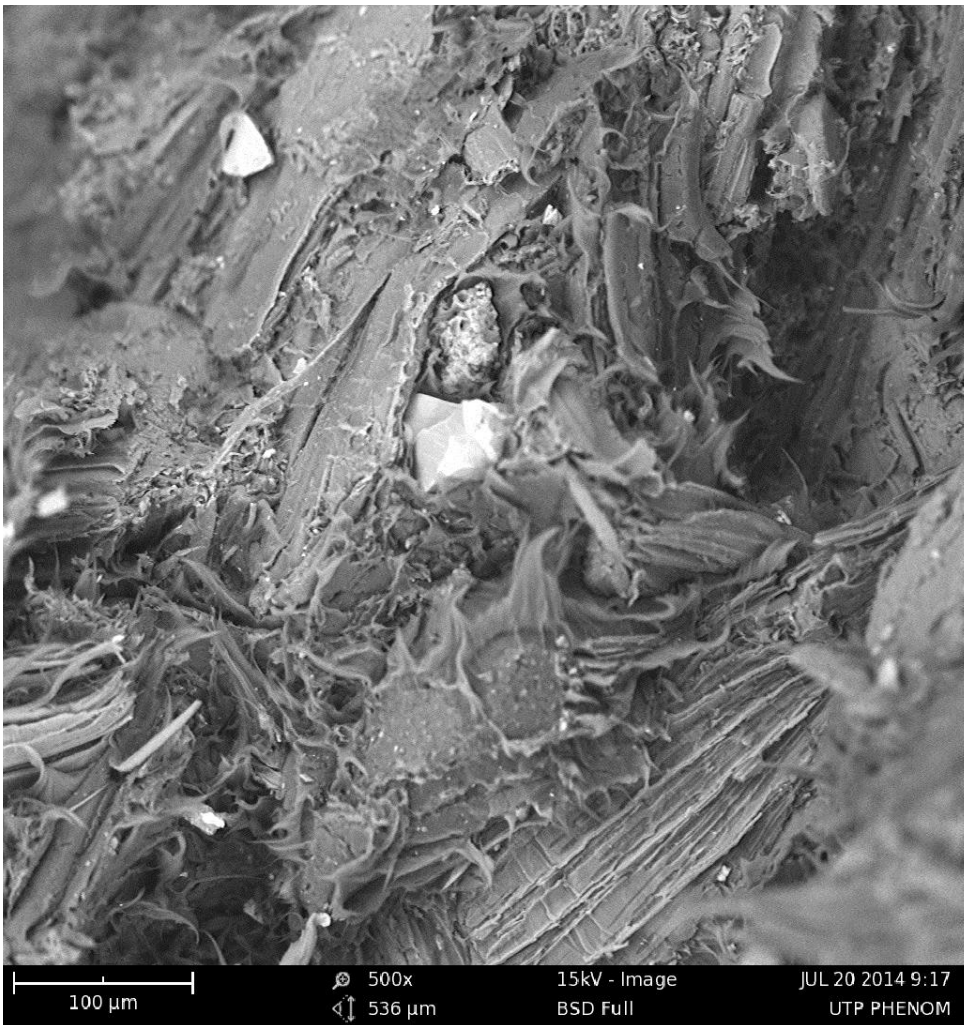

Figure 18: SEM for sample C with composition of 75:25, LDPE:sawdust composite

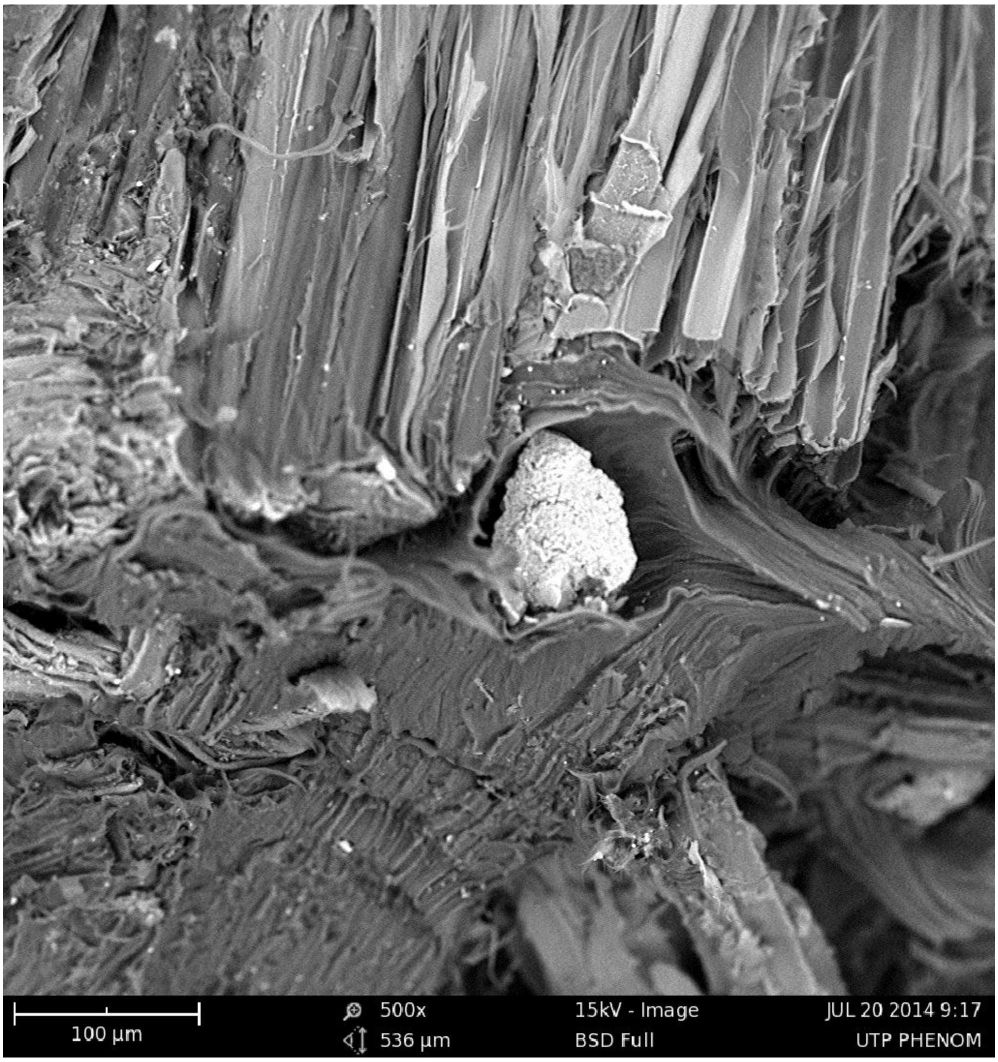

Figure 19: SEM for sample D with composition of 75:25, LDPE:sawdust composite

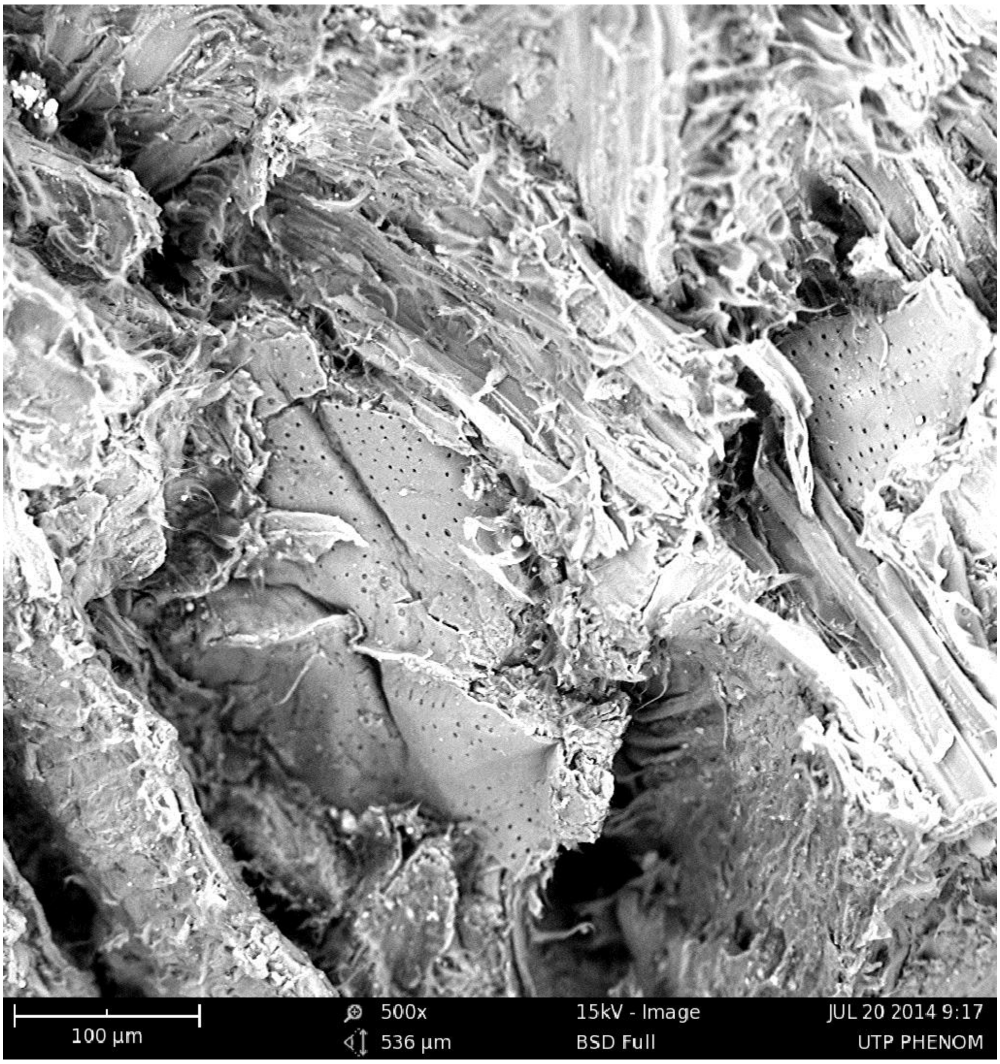

Figure 20: SEM for sample C with composition of 60:40, LDPE:sawdust composite

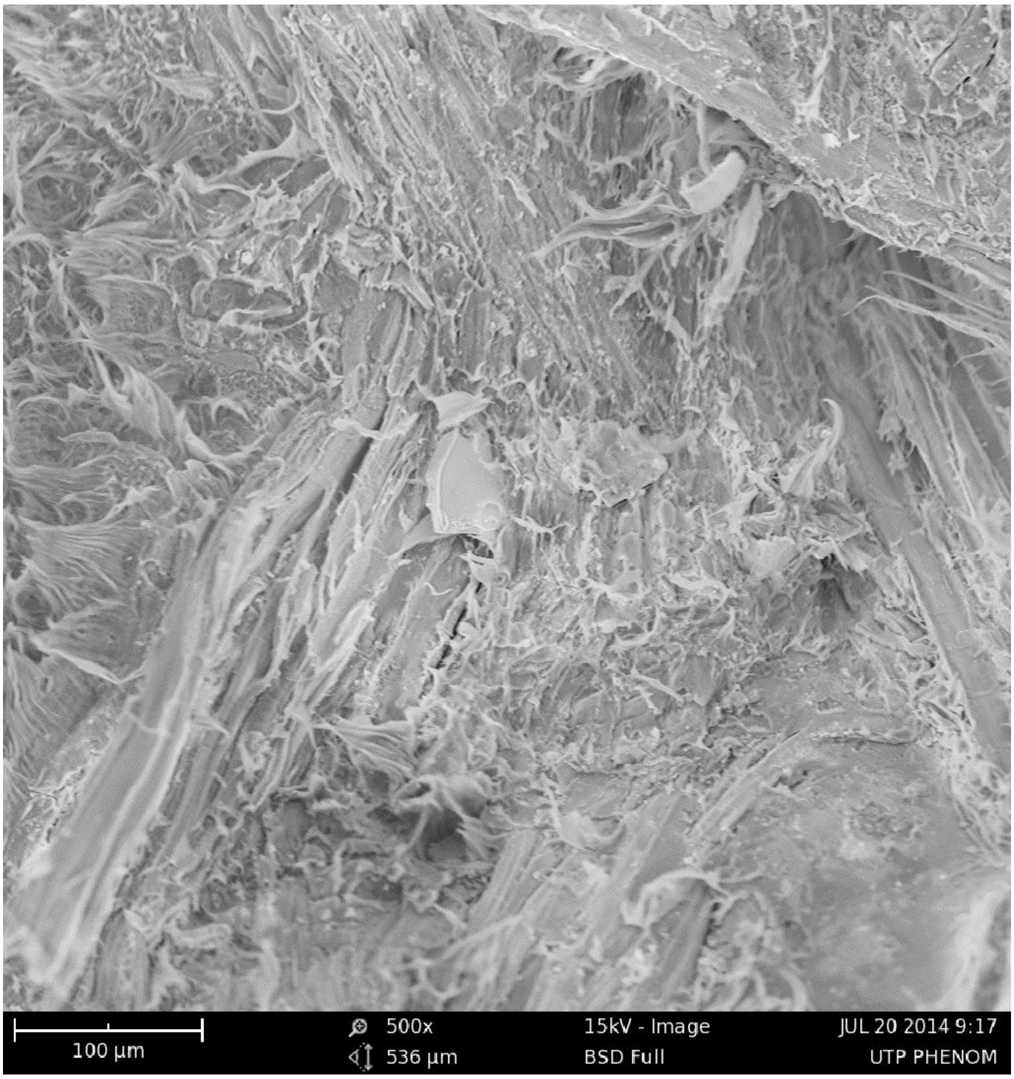

Figure 21: SEM for sample C with composition of 90:10, LDPE:sawdust composite

4.8.2 Discussion

Figure 16 until 21 shows the difference in morphology of the composite boards produced by varying the production parameter by SEM. The microstructure clearly shows that when different range of sawdust particles size was added to LDPE, morphological change in the structure took place. The microstructure reveals that there were small discontinuities and a reasonably uniform distribution of sawdust particles and LDPE.

The dark part show the LDPE while the white part is the sawdust particles. It can be compared that less coverage of the LDPE for sample A followed by sample B, C and D. This shows that the smaller size particles of sawdust used in the sample will increase the area for water absorption and decrease the mechanical strength of the composite.

For the different composition, it can be seen that as we increase the amount of sawdust particles in the sample, the sawdust particles are poorly detached to the LDPE surface. This is due to the poor interfacial bonding between the LDPE and sawdust particles (Atuanya, Ibhadode, & Igboanugo, 2011).

Generally, the SEM shows a small discontinuities and unevenly distribution of LDPE and sawdust particles. This is due to the surface of the sawdust particles itself that are not smooth providing poor compatibility between the LDPE and sawdust particles (Atuanya, & Solomon, 2011).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The introduction of LDPE to form sawdust polymer composite shows the positive result on the physical and mechanical properties of the composite. The range of size for sawdust particles used in the sample affected the results on every test conducted. By changing the parameter according to the composite loading, we can see that as the amount of LDPE increases, the mechanical strength of the composite increases. From all the experiment also, we can conclude that sample C with the range of sawdust size of $0.425 \leq x \leq 0.599$ mm with composition of 90:10, LDPE:sawdust have the best physical and mechanical properties. The study shows that the introduction of LDPE sawdust composites has higher potential to be commercialized and replace wood-based product in the future.

5.2 Recommendation

From the study, it shows that the distribution of LDPE and sawdust particles in the sample will effect on the result obtained. Therefore, the method of preparing the sample should be improvised as some of the sample might not be evenly distributed between the LDPE and sawdust particles during the molding process. Other than that, in order to get the good average data, every test should be repeated many times and the longer time should be provided to allow more sample can be prepare. Lastly, more research on the sawdust composite combining with other type of polymer should be done in other to counter the issue of higher demand in wood based product.

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APPENDICES

Sieving Analaysis

Figure 22: Sieving machine used to sieve the sawdust particles according to the size.

Water absorption for raw sawdust

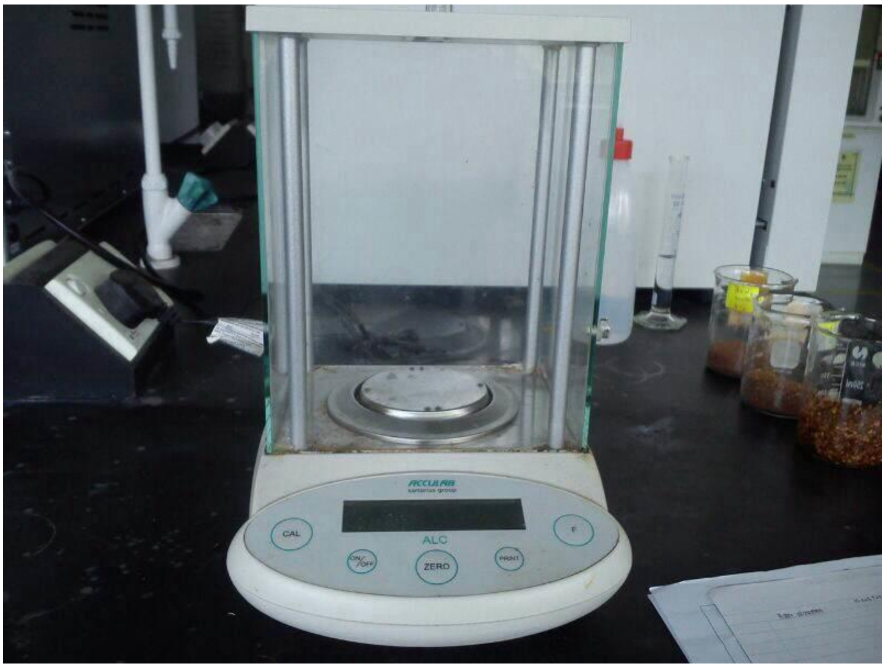

Figure 23: Weighing balance used to weigh the sawdust particles.

Figure 24: An oven used to put the sawdust at 100^0C.

Figure 25: Sawdust after drying in the oven for one day.

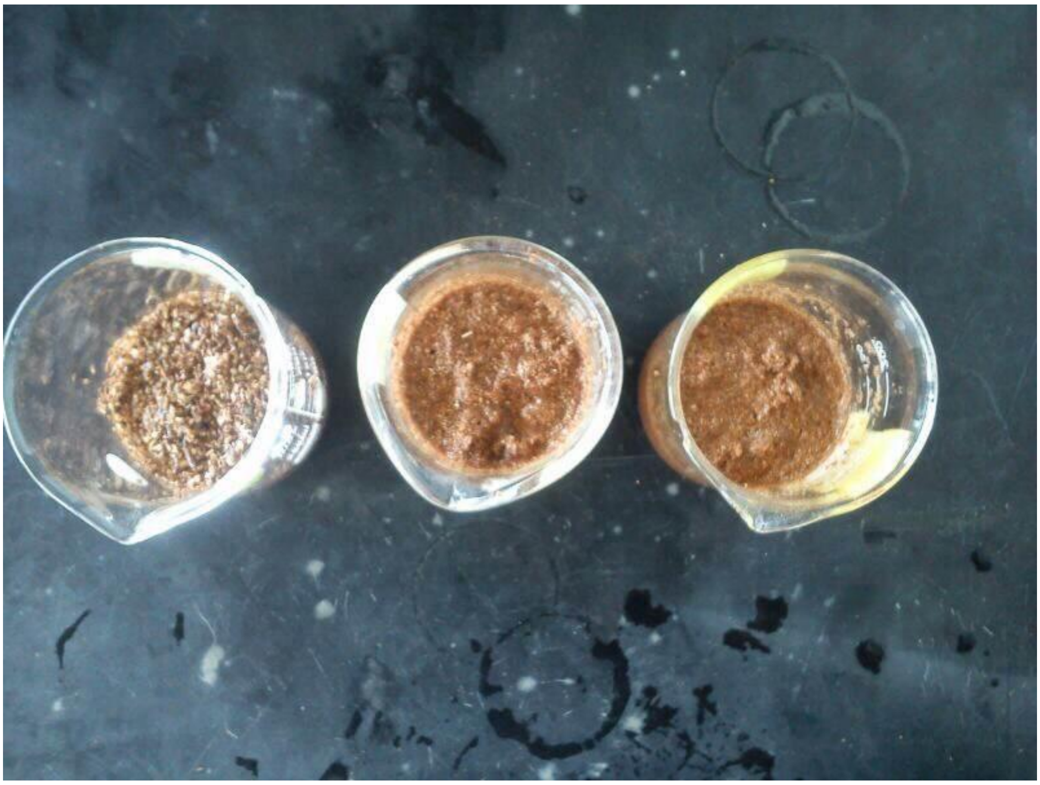

Figure 26: Sawdust after being immersed in 65ml of distilled water.

Sample preparation

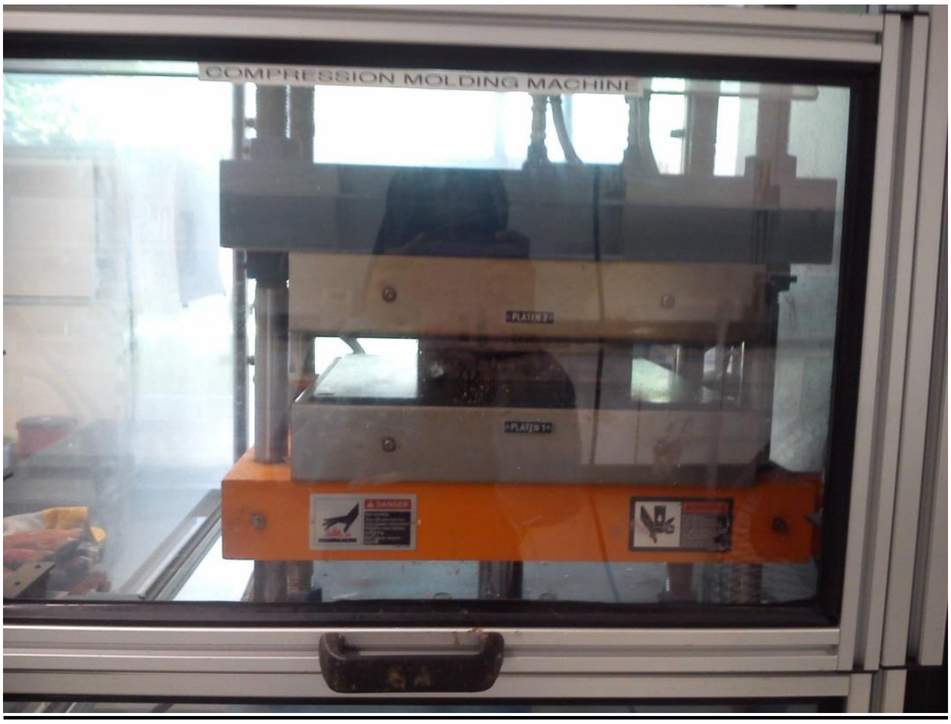

Figure 27: Compression molding machine used to mold the samples.

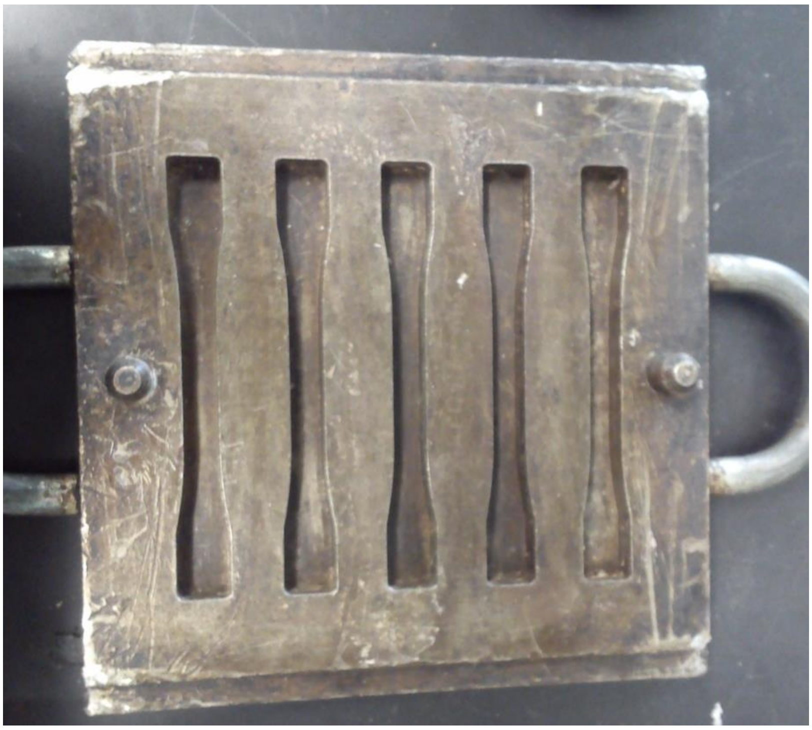

Figure 28: Example of mold used to prepare the samples.

Water absorption test

Figure 29: Samples being immersed in 50mL water for 24 hours.

Figure 30: Condition of some of the samples after being immersed in water.

Tensile strength test

Figure 31: Some of the samples for tensile strength test.

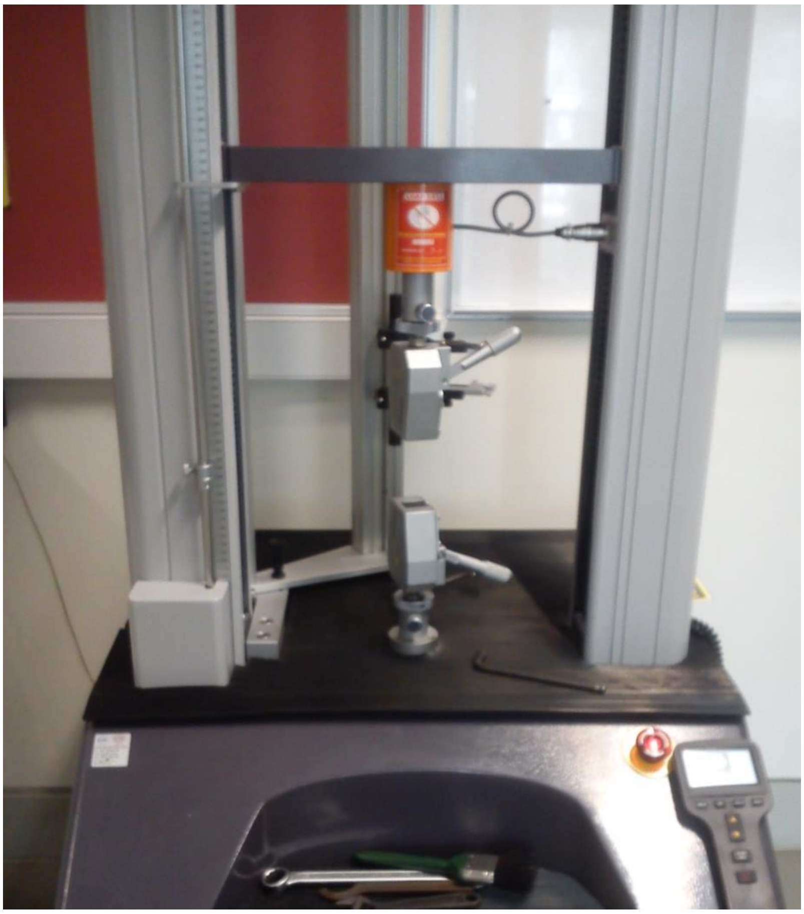

Figure 32: Tensile machine used to test on the tensile strength for every sample.

Figure 33: One of the samples had been placed in the tensile machine to be tested.

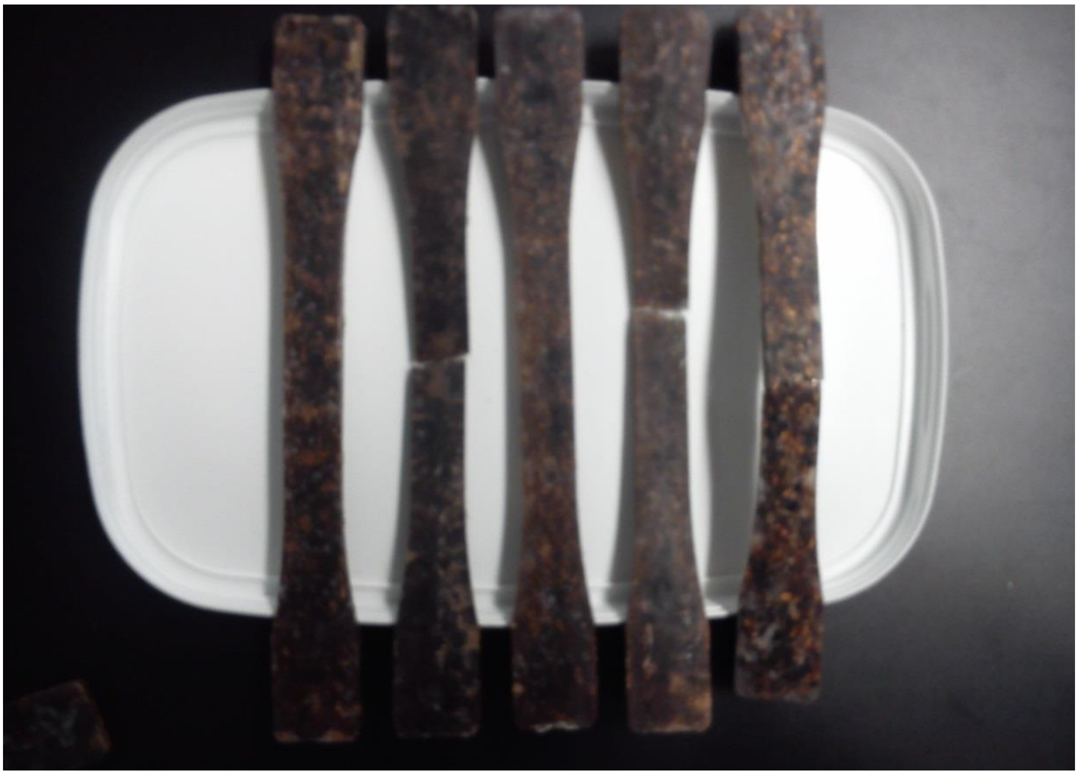

Figure 34: Some of the sample for flexural test after being tested.

Flexural test

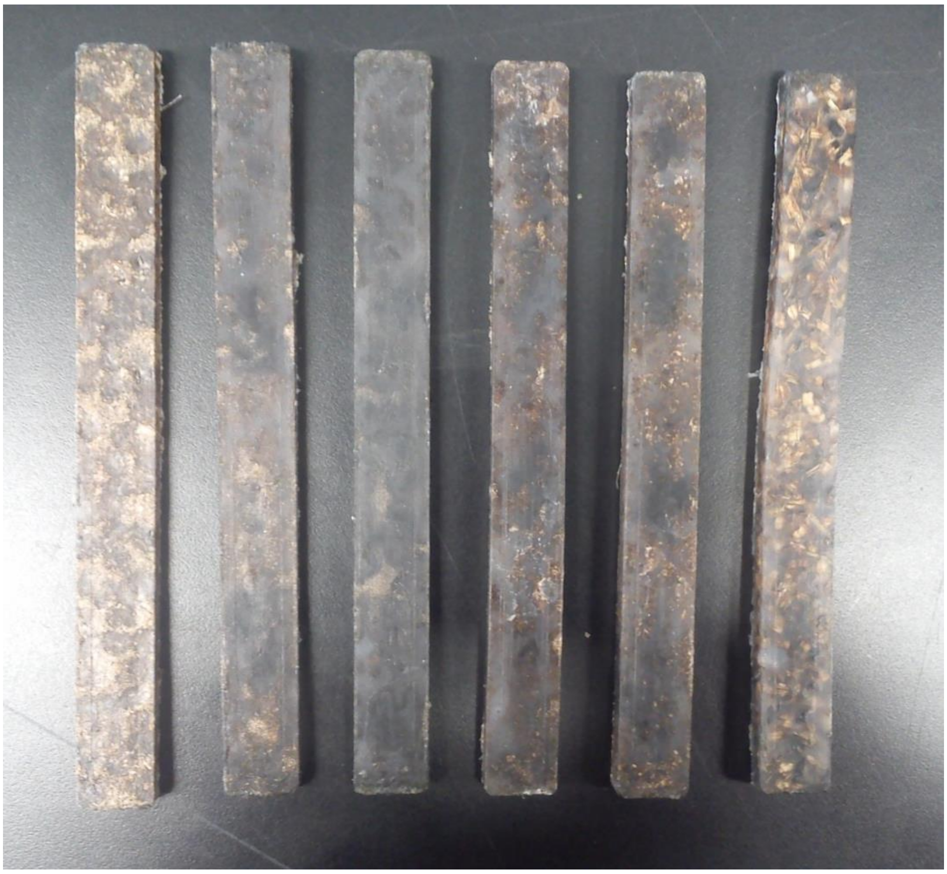

Figure 35: Some of the samples for flexural test.

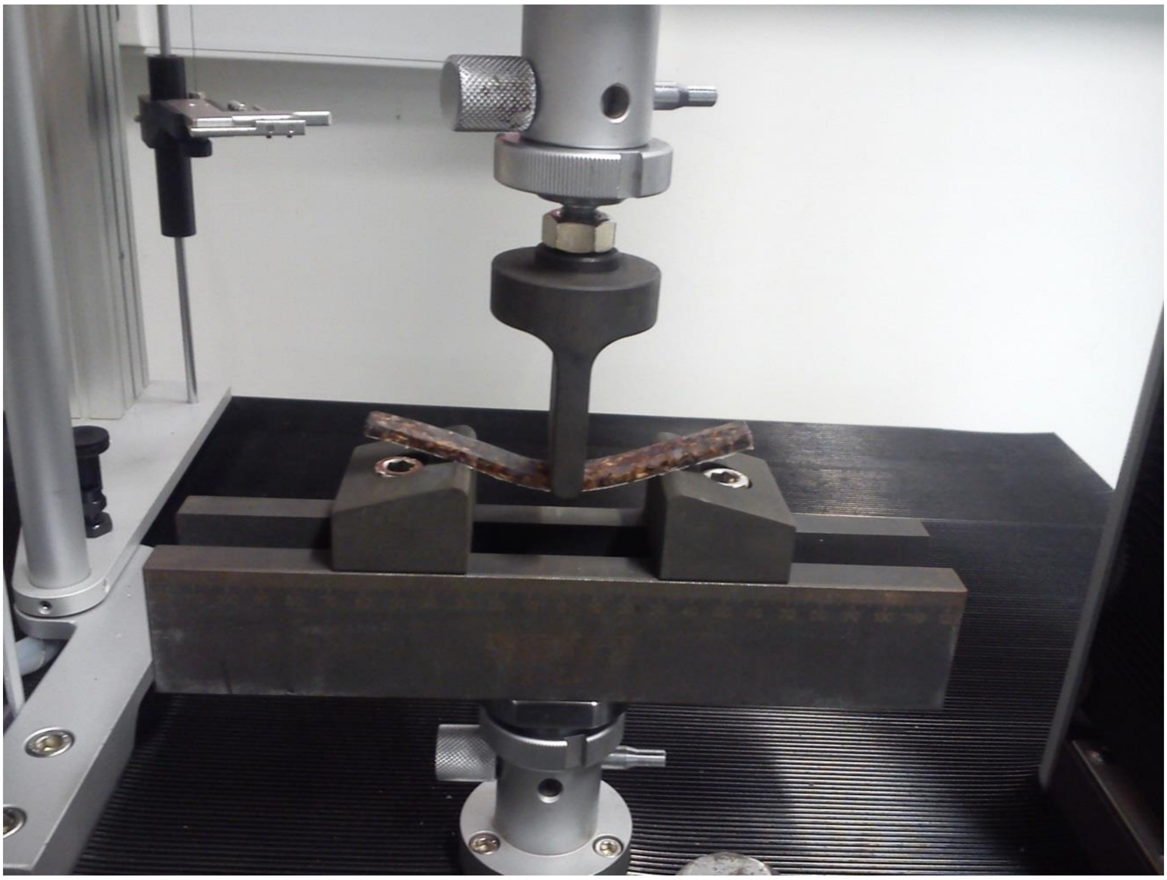

Figure 36: One of the samples had been placed in the flexural machine to be tested.

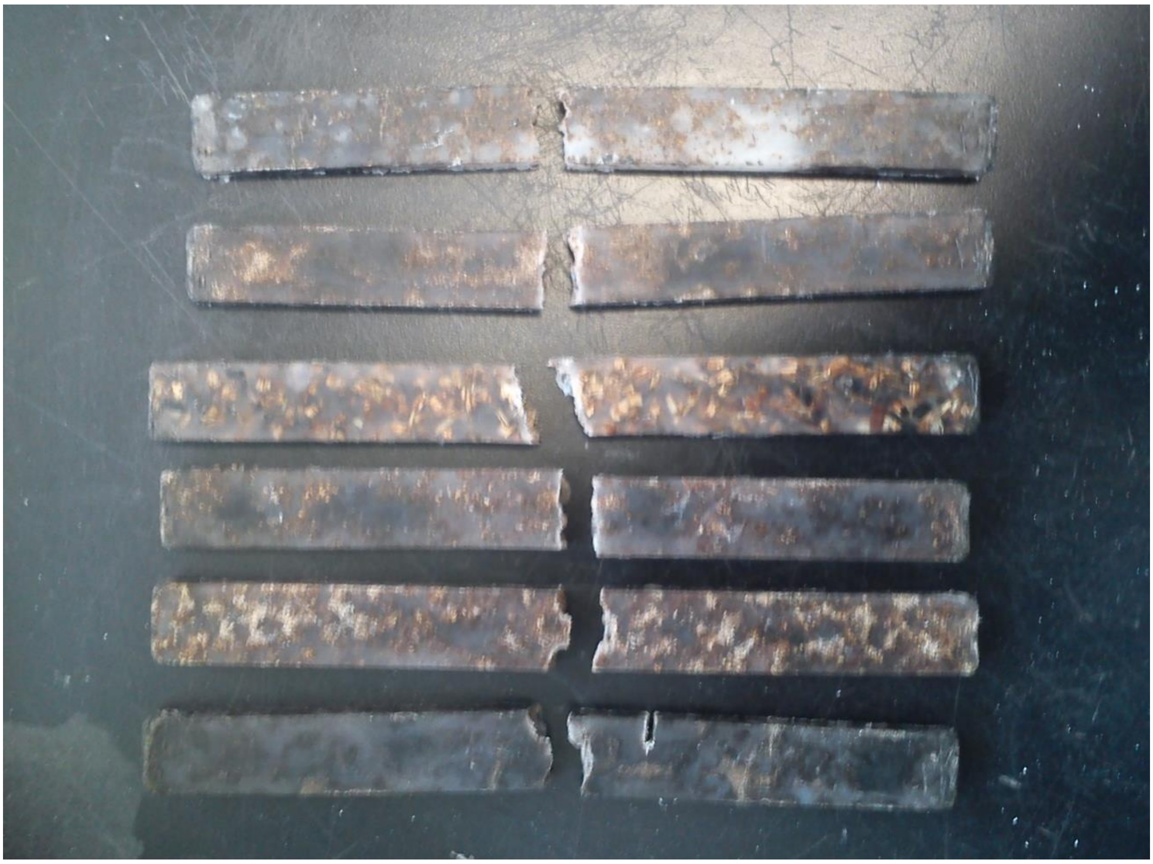

Figure 37: Some of the sample for flexural test after being tested.