MECHANICAL PROPERTIES OF JUTE FIBER POLYESTER HYBRID COMPOSITE FILLED WITH EGGSHELL

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DEDICATION

This research is wholeheartedly dedicated to my beloved parents, who have inspired me, helped me when I was on the verge of giving up, and who consistently offer their moral, spiritual, emotional, and financial support. To my brother, sisters, family members, friends and my supervisor, Dr. Najiyah Safwa binti Khashi'ie, who have offered me words of encouragement and wisdom. Finally, I would like to thank Allah for providing me with a healthy life and thank Him for giving me guidance, strength, mental power, protection, and abilities.

ABSTRACT

Natural fibres are being used in composites as a means of environmental protection through the use of biodegradable components. By combining natural and synthetic fibres, the use of natural fibres might be expanded significantly, potentially lowering the cost of hybrid composites. Fibre reinforced polymer-based composites have been used in a wide range of industrial applications for a very long time because of their high specific strength and modulus. The use of coir, a natural fibre, as reinforcement in reinforced polymers was decided upon due to the availability of different natural fibres. Natural fibres are equally as strong and light as they are affordable. As therefore, the aim of this research is to analyse the mechanical characteristics of a jute fiber/polyester hybrid composite filled with eggshell. In this study, woven jute fibres and polyester filled with eggshell powder were employed to construct composites utilising the layering technique. In accordance with ASTM standards, tensile, flexural, impact, and water absorption tests will be performed to assess the influence of ratio. Five eco-friendly ratios were employed: 80% eggshell powder and 20% polyester, 70% eggshell powder and 30% polyester, 50% eggshell powder and 50% polyester, 40% eggshell powder and 60% polyester, and 20% eggshell powder and 80% polyester. The following steps for this research are fabricating the sample, testing the specimen and lastly data analysis. Each process must be understood and analyzed using the correct procedure and ASTM standard. Next, the average of the testing result needs to be analyzed using ANOVA analysis. Last but not least, the outcome of the eggshell powder reinforced by polyester resin must be able to produce the best composite ratio.

ABSTRAK

Gentian semulajadi digunakan dalam komposit sebagai satu inisiatif untuk melindung alam sekitar melalui penggunaan komponen biodegradasi. Dengan menggabungkan gentian asli dan sintetik, penggunaan gentian semula jadi mungkin diperluas dengan ketara, yang secara tidak langsung berpotensi mengurangkan kos komposit hibrid. Komposit berasaskan polimer bertetulang gentian telah digunakan dalam pelbagai aplikasi perindustrian untuk masa yang sangat lama kerana kekuatan dan modulus spesifiknya yang tinggi. Penggunaan sabut, gentian asli, sebagai tetulang dalam polimer bertetulang telah ditentukan kerana ketersediaan gentian asli yang berbeza. Gentian semulajadi adalah kuat dan ringan serta ia mampu dimiliki. Oleh itu, tujuan penyelidikan ini adalah untuk menganalisis ciri-ciri mekanikal komposit gentian jut/poliester hibrid yang diisi dengan kulit telur. Dalam kajian ini, gentian jut tenunan dan poliester yang diisi dengan serbuk kulit telur digunakan untuk membina komposit menggunakan teknik pelapisan. Selaras dengan piawaian ASTM, ujian tegangan, lentur, hentaman dan penyerapan air dilakukan untuk menilai pengaruh nisbah. Lima nisbah mesra alam telah digunakan: 80% serbuk kulit telur dan 20% poliester, 70% serbuk kulit telur dan 30% poliester, 50% serbuk kulit telur dan 50% poliester, 40% serbuk kulit telur dan 60% poliester, dan 20% serbuk kulit telur dan 80% poliester. Langkah seterus kajian ini adalah memfabrikasi sampel, menguji sampel dan akhir sekali menganalisis data. Setiap proses perlu difahami dan dianalisis menggunakan prosedur dan standard ASTM yang betul. Seterusnya, purata keputusan ujian perlu dianalisis menggunakan analisis ANOVA. Akhir sekali, hasil serbuk kulit telur yang diperkukuh oleh resin poliester mestilah dapat menghasilkan nisbah komposit yang terbaik.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
CNC	-	Computer Numerical Control
SDG	-	Sustainable Development Goal
CaCO3	-	Calcium carbonate
EP	-	Eggshell Powder
ρ	-	Density
m	-	Mass
v	-	Volume
σf	-	Flexural Strength
P	-	Force
L	-	Length
b	-	Width
d	-	Depth
k	-	Number of Independent Comparison Groups
n	-	Total Sample Size
SSB	-	Sum of Square Between
SSW	-	Sum of Square Within
SST	-	Total Sum of Squares
MSB	-	Mean Sum of Squares between the groups
MSW	-	Mean Square within groups
SS	-	Sum of Squares
MS	-	Mean Square
80EP20PR	-	80% of eggshell and 20% of polyester
70EP30PR	-	70% of eggshell and 30% of polyester
50EP50PR	-	50% of eggshell and 50% of polyester
40EP60PR	-	40% of eggshell and 60% of polyester
20EP80PR	-	20% of eggshell and 80% of polyester
EPPR	-	Eggshell Polyester Resin

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CHAPTER 1

INTRODUCTION

1.1 Background

One of the most important environmental issues in Malaysia is the management of solid waste. The Malaysian recycling rate has increased by 33.17% in the last update from 2022 with a total of 4.626 million tonnes of discarded articles, as per Malaysia Insight (2022). In comparison to the developed nations, such as Germany and Austria, Malaysia is far from where it should be. If this problem isn't urgently tackled, the World Bank (2018) forecasts that global waste will be up to 70% higher in 2050 than it is today. The promotion of recycling rates through the introduction of waste-based products or materials development is one of the most urgent actions that governments can take.

One of the waste-based materials is eggshells. Eggshells are widely used in the food industry due to their taste, excellent protein sources, and it is relatively easy to obtain. Despite the various uses of eggs, the after problem occurred is that the large quantity of eggshells waste became hard to manage as this material can only be disposed at landfills with odour production and microbial growth (Mignardi et al.,2020).

Other materials that will be used are jute fabric and polyester. Jute fabric is a type of textile made from a plant called jute. Fibers from jute plants are harvested in a single long string because it can grow over 10 feet high. Thus, it makes jute fibers one of the longest natural textile fibers in the world (Sewport, 2021). Jute fiber is commonly utilized to produce packaging, fabrics, carpets, ropes, etc. On the other hand, polyester is used in this research to act as synthetic fiber that combines synthetic polymers to form a fiber. Polyester is widely used due to its mechanical resistance and good at stretching and shrinking without loss of strength.

Building a waste-based product that has a long lifetime, especially in terms of design and proportion, is at risk of damaging the structure of product. Therefore, it's crucial to use materials that have the mechanical qualities of durability, compressive strength, tensile strength, and flexibility. On top of that, the correct ratio must be identified by doing multiple experiments. This materials and proportion selection can be done in the planning process to avoid any wrong choice.

This research aims to fabricate a jute fiber polyester hybrid composite filled with eggshells and investigate the mechanical properties of fabricated materials using three different types of testing.

1.2 Problem Statement

The problem statement in this research revolves around the management of solid waste in Malaysia, particularly focusing on the challenges posed by the large quantity of eggshell waste. Despite the increased recycling rate in Malaysia, it remains significantly lower than that of developed nations. The excessive disposal of eggshells, known for their difficulty in management due to odor production and microbial growth, is highlighted as a pressing issue. The research aims to address this problem by proposing the creation of a waste-based product, specifically a jute fiber-polyester hybrid composite filled with eggshells. The primary concern is to investigate the mechanical properties of this composite, emphasizing the need for materials with qualities like durability, compressive strength, tensile strength, and flexibility. The goal is to develop a sustainable solution that not only manages waste effectively but also contributes to environmental conservation.

1.3 Research Objective

The main purpose of this research is to investigate the mechanical properties of jute fiber polyester hybrid composite filled with eggshell. To be specific, the objectives are:

a) To fabricate an eggshell-filled, hybrid jute-polyester composite.

b) To analyze the mechanical properties of fabricated materials using tensile, flexural, impact and water absorption tests.

c) To identify the statistically significant differences on various reinforced composite ratios.

1.4 Scope of Research

The scope of this research are as follows:

1. Study on mechanical properties of hybrid jute, eggshells and polyester.
2. Fabricating materials using five different ratios: 80P20EP, 70P30EP, 50P50EP, 40P60EP and 20P80EP.
3. Fabricating the materials by using the hand lay-up technique.
4. Cutting the fabricated materials into the testing specimen using the CNC router machine with a thickness of 0.3 cm.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, research regarding waste-based material is done to solve environmental issues such as pollution that are caused by disposal problems. This existing issue could lead to bad lifestyle, habits as well as health. Each research comes with more exposure and vigilance of solving this issue. Followed by that, few alternatives or ways have been performed. There are many samples and products that were produced with the involvement of various aspects such as in terms of society awareness and engineering.

To come up with a better solution, many professionals' studies towards waste-based materials are continued. The great way to deal with the environmental issue is to produce a hybrid composite material that is filled with natural material. This solution can be carried out without maximizing the production cost. Figure 2.1 shows the literature review in Ishikawa Fishbone Diagram to produce jute fiber polyester hybrid composite filled with eggshell.

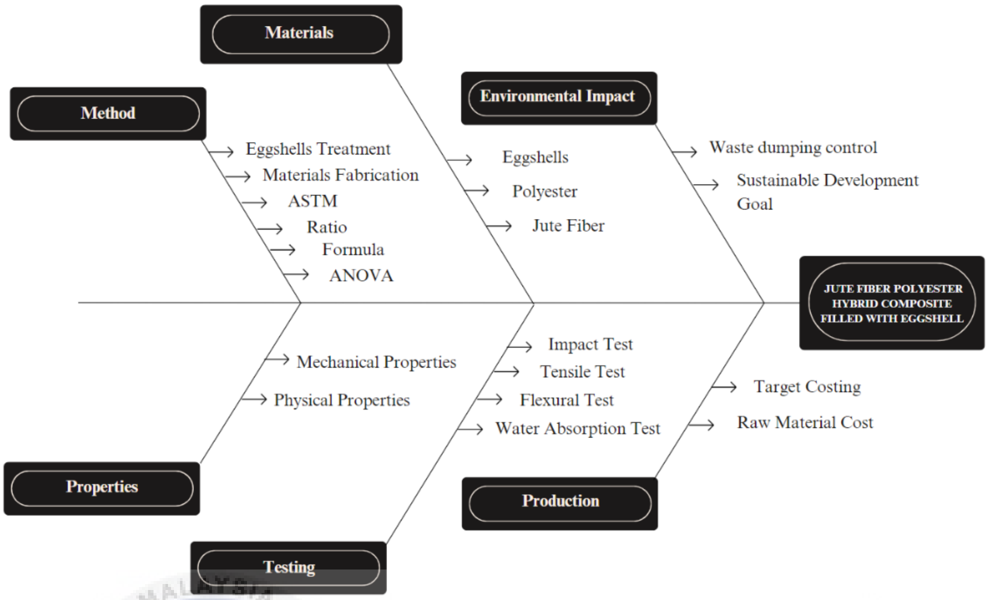


Figure 2.1: Ishikawa fishbone diagram of producing jute fiber polyester hybrid composite filled with eggshell

2.2 Environmental Impact

Beyond the evaluation of mechanical properties, environmental effects of manufacturing, usage, and disposal must be taken into account when developing conventional material alternatives. If environmental impacts are greater than those of conventionally available materials, the production of a "green" material alternative is of limited benefit (Pietrini et al., 2007).

2.2.1 Waste Based Material

According to Turunen and van der Werf (2006), environmental impact assessments are often performed for the production of a specific mass or volume of material. This constrained scope of evaluation makes sense when the preferred application and material attributes are not known. However, if the use of these alternative materials is not taken into account in regard to their environmental impact, it may lead to an incorrect portrayal of predicted environmental implications.

A waste-based material that consists of natural fiber composite gives a higher potential for various aspects in waste management. According to Baillie et al. (2009), waste-based products give a big advantage on poverty reduction, especially in terms of developing communities where waste scavenging frequently happened. In addition to that, the mixture of natural fibers and thermoplastic like polyester has higher potential to save non-renewable resources and serve as a sustainable 'sink' for atmospheric carbon dioxide (Pervaiz and Sain, 2003).

2.2.2 Sustainable Development Goal

The United Nations General Assembly (UNGA) developed the Sustainable Development Goals in 2015 to ensure the sustainability of humankind on Earth. The 17 Sustainable Development Goals (SDG) are broken down into three categories: economic, social, and environmental. In order to advance global health and well-being, promote the eradication of all forms of inequality and poverty, support climate action, quality education, gender equality, peace, and social justice, the Sustainable Development Goals (SDGs) were suggested. The targets (which range from five to twelve targets per goal) explicitly explain the goals.

SDGs include relevant bio-industrial products, biorefineries, and biomass materials. Academic effect of the education and research sector promotes the creation of innovative materials and the use of relevant technology in order to promote and be aware of the goals. Due to their carbon-neutral content, biomass materials are currently one of the key sources. Additionally, biomass materials are generally utilized and are one of the distinctive sources in every nation, which might help in promoting the activities. For instance, cellulose and chitin are the most varied components from plants and food wastes that are common in nature, out of all the biomass sources (Kobayashi, 2015). The SDGs 12 serve as a framework for measuring how people support recycling and reducing food waste. Such cellulose could be transformed into composites, biodegradable films, and carbon fibers during industrial regeneration (Vincent et al., 2018). Figure 2.2 below presents the infographic of SDG 12 (United Nation, 2022).

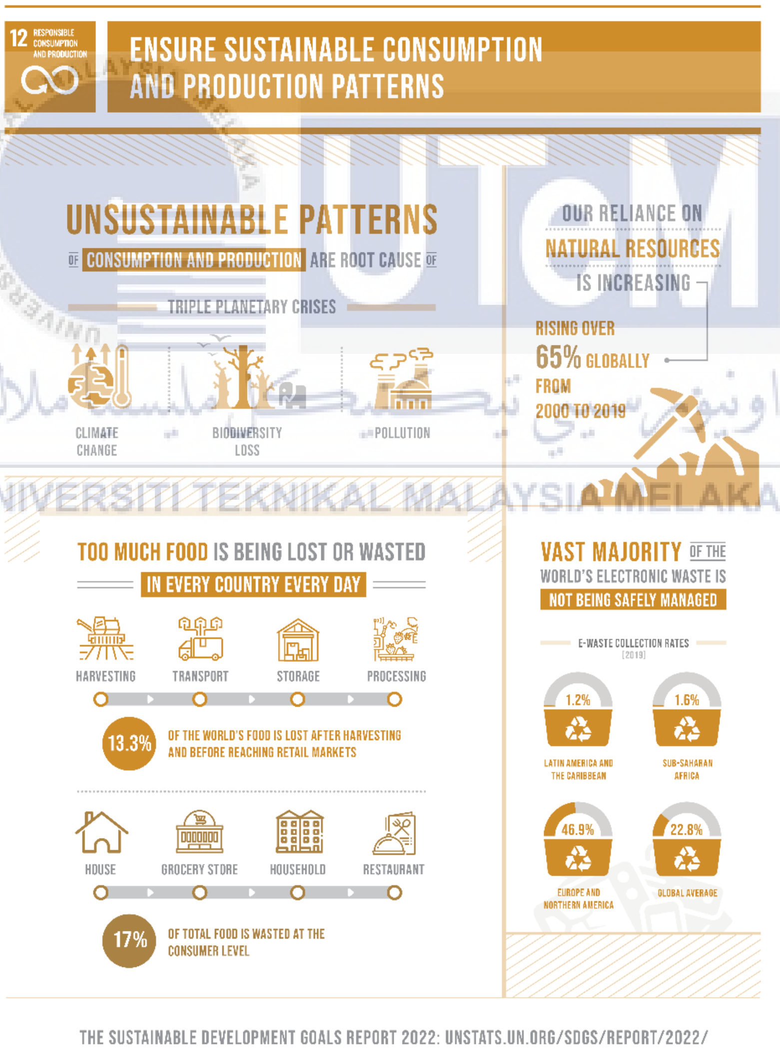


Figure 2.2: Infographic of SDG 12 (United Nation, 2022)

The issue of recent microplastic pollution has also accelerated the use and promotion of these biomass materials because it is still unknown how harmful microplastic pollution is to the environment and human health (Provencher et al., 2020). Thus, biomass plastics are goods that make the best possible use of organic resources and have the following benefits of biomass sustainable resources: circulation, natural symbiosis, carbon-neutral and catalytic degradation, and biodegradable decomposition without burning.

2.3 Material Properties

To produce a high-quality product, the most important thing to be taken into account is material selection. For this research, it is important to consider various conditions and aspects such as temperature, tensile strength and impact strength. The materials chosen are eggshells, jute fiber fabric and polyester.

2.3.1 Eggshells

For the past fifty years, many studies have been done regarding the quality of eggshells. During that period, the change of many aspects is dramatically happened such as chicken's genetics, diets, management practices, etc. Those aspects are associated and genuinely some of the main factors that could affect the quality of eggshells.

The majority of premium eggshells from industrial layers include 2.2 grammes of calcium in the form of calcium carbonate. According to Butcher and Miles (1990), 95% of the dry eggshell is composed of calcium carbonate, which has a mass of 5.5 grammes. Sodium, potassium, zinc, manganese, iron, copper, and tiny amounts of iron, phosphorus, and magnesium can all be found in small amounts in the average eggshell. If the calcium from the shell is removed, the organic matrix substance is still present. Because this organic material can bind calcium, how it is organized during shell development influences how strong the shell will be. Multiple CaCO3 layers are present in eggs and are developing together. Eggshell powder ash had 0.84 specific gravity.

The organic material must be deposited for the crystalline elements, primarily calcium carbonate, to have the proper size and arrangement in order to form a strong shell. Most of the real shell is made up of calcium carbonate in the form of lengthy columns. Other zones that participate in self-organization contribute to the eggshell's attributes of strength. Therefore, while there are other factors that affect strength, shell thickness is the primary one. Currently, dietary modification is the main strategy used to address eggshell quality issues. However, the relationship between the organic membrane and the shell must also be taken into account if the shell is to be of high quality.

2.3.1.1 Composition and Sources of Eggshells

Numerous disorders, including low calcium levels, are treated with calcium carbonates. In fact, metamorphic marbles and sedimentary rocks like limestone or calcites, which are regularly mined from quarries or underground, contain calcium carbonate as a mineral. In nature, calcium carbonate occurs as three different crystal polymorphs with varying degrees of stability: calcite, aragonite, and vaterite (Cölfen, 2013). Calcite makes up the majority of limestone, chalk, and marble. The density of natural limestone ranges from 2.50-2.71 g/cm^3. According to studies by Patnaik et al., (2020) and Cao et al. (2016), mentioned that fillers in polymer composites and raw materials used to manufacture cement and mortar have been its main applications for engineering material. There are a lot of industrial waste materials that contain large quantities of calcium carbonate in the form of chicken eggshells, as well as mineral limestone.

2.3.1.2 Eggshell Structure and Composition

An empty shell ranged in weight from 6.6 to 7.3 g, whereas an average egg weighed between 60.0 and 60.2 g (John-Jaja et al., 2016). The kind of chicken feed used, as well as any contaminants produced from organic proteins and membranes, may have had an impact on the makeup of the sample.

The amount of calcium carbonate cannot be determined by the color of the shell. For example, brown eggshells were reported to contain 96–97% calcium carbonate and 3–4% organic membrane (Intharapat, P.; Kongnoo, A.; Kateungngan, K.), while white eggshells were found to have 94% calcium carbonate content with 6% organic membrane (Okonkwo, U.N.; Odiong, I.C.; Akpabio, E.E.). Based on the research by J. Compos. Sci. 2020, it has been considered that calcium carbonate is equal in both Brown and White eggshells. From a variety of studies, the eggshell density has been quantified; 2.50 g/cm^3, 2.53 g/cm^3, 2.59 g/cm^3 and 2.62 g/cm^3. The density of eggshells is slightly lower than mineral limestone, which may be due to the shell's porous nature (Vijayvenkatesh et al., 2018). In another research, eggshells had a density of 0.4236 g/cm^3 according to ASTM-679 values (Hassen, et al., 2015). This concomitantly summarized that density of eggshells is slightly less than mineral limestone, which may be because they are porous.

2.3.2 Jute Fiber-Polyester

Polymer matrix composites are formed from a combination of polymer resins and any sort of reinforcing agent. A simple process of fabrication, cheaper cost, and beneficial features, such as good thermal and electrical insulators and lower density, are the advantages of these composites. Type of polymer, reinforcing material, and filler material are the three factors that should be taken into account when determining a material's properties. Polymer matrix is regarded as the most important class of composite, in contrast to metal matrix and ceramic matrix. There are two categories of polymer matrix: thermoplastic polymers and thermoset plastics.

Jute fiber reinforced composites with polyester and epoxy resin matrices have been studied for their mechanical properties by Gopinath et al. (2014). The study's findings are depicted in Figure 2.3, which compares the impact strength of several jute-reinforced epoxy-polyester composites. According to the outcome, polyester-based composites have more potential for impact strength than epoxy-based composites. Impact strength measurements for the polyester-based composite were 118.28 J/m^2, while those for the epoxy-based composite were 70.04 J/m^2.

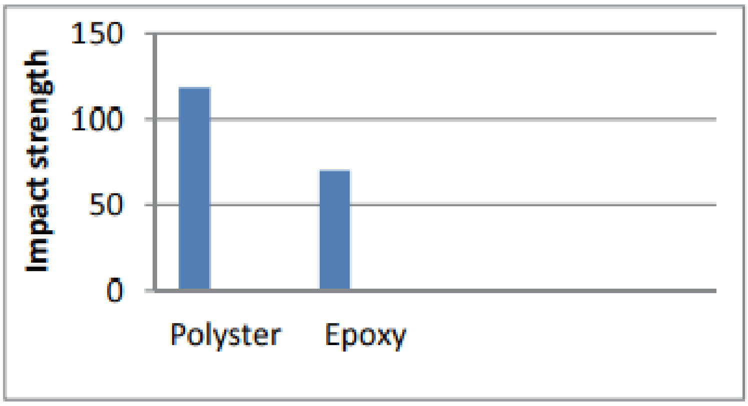


Figure 2.3: Bar graph of comparison between impacts strength of jute reinforced epoxy/polyester composite (Gopinath et al., 2014)

2.4 Method

This section is focused on the methods related that will help to enhance the performance of this research, including the fabrication of materials, mechanical testing and ANOVA analysis.

2.4.1 Eggshells preparation

Raw eggshells go through a limited number of processes (Kowshik et al., 2022; Hiremath et al., 2018). To get rid of any remaining albumen and/or other protein material and/or contaminants stuck, the used chicken eggshells that were purchased from the neighbourhood business area, such as bakeries, were first washed with water. In order to reduce the moisture content, eggshells are next mechanically ground as Figure 2.4 (Hiremath et al., 2018) after drying in the sun for a day. The processes of obtaining the uncarbonized and carbonized eggshell fillers are presented in Figure 2.5 (Kowshik et al., 2022).

Figure 2.4: Egg shell powder (Hiremath et al., 2018)

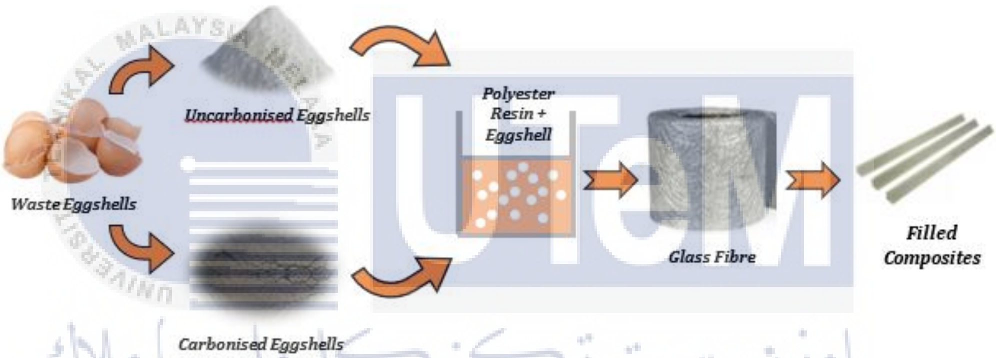


Figure 2.5: Activities involved in the processing of eggshells to obtain uncarbonized and carbonized eggshell fillers (Kowshik et al., 2022)

2.4.2 Hand Lay-up Method

Hand lay-up is a traditional open moulding technique to produce composite. Simple procedure is first started with placing the dry fibers into the mould and followed by applying the resin matrix on the reinforcing material.

Kowshik's (2022) composite are divided into four different variations by using the hand lay-up technique. E-glass fiber mats with 450 GSM that are made of chopped glass fiber strands arranged randomly were used as reinforcement. Polyester resin was used as matrix material during manufacture. Methyl-ethyl-ketone peroxide (MEKP) was the hardener utilized in the procedure. 12:1 ratio of hardener-to-resin was used to combine both hardener and resin. Using a mechanical stirrer, the eggshells were then combined with polyester resin. The mixing ratio is displayed in Table 2.1.

Table 2.1: Composite variants and their composition (Kowshik, 2022).

Composite Variant	Glass Fiber (wt.%)	Polyester (wt.%)	Uncarbonized Eggshell (wt.%)	Carbonised Eggshell (wt.%)
Unfilled (UF)	34	66	0	0
Uncarbonised eggshell filled (UCES)	34	56	10	0
Carbonised eggshell filled (CES)	34	56	0	10
Hybrid eggshell filled (HY)	34	56	5	5

2.4.3 Mechanical Testing

The main purpose of this research is mechanical testing. When establishing material qualities or providing certification for final goods, safety is crucial. Testing is also essential to guarantee technical growth, superiority and a design that is both inexpensive and efficient. Four characterization tests of the hybrid composite: tensile test, flexural test, impact test, and water absorption test will be used to conduct an experimental examination of the mechanical properties on the eggshell polyester resin (EPPR). All fabricated materials are cut into the testing specimen using the CNC router machine.

2.4.3.1 Tensile Test

Tensile testing is a destructive test technique that provides data regarding the tensile strength, yield strength, and ductility of the material. It evaluates how much stretching or elongation a composite specimen must endure before it breaks.

The ASTM D3039 specification has been followed in the preparation of the specimens for tensile testing. The samples were 250 mm long and 25 mm wide, respectively. The total composite thickness was 6.8 mm during sample testing, with a range of 0.2 mm, and the space between the grippers was 100 mm. According to Sujon et al. (2020), the load is applied to a sample until the universal test device with a crosshead speed of 5 mm per minute fails.

2.4.3.2 Flexural Test

Flexural testing determines how much force is required to bend a plastic beam and evaluates a material's stiffness or resistance to bending. The flex modulus of the material indicates how far it can bend before permanently deforming.

ASTM D790 has been followed for conducting flexural testing or three-point bending tests. Each specimen measured 250 mm long and 25 mm wide. The crosshead speed has been set at 5 mm per minute, with a span distance of 100 mm between supports for all samples. Based on the average values from five comparable samples, the analysis was conducted (Sujon et al., 2020).

2.4.3.3 Impact Test

A material's ability to withstand the impact is tested in an impact test, which determines how much energy is absorbed by the material before it fractures. According to research by Sujon et al., (2020), the ASTM D6110 standard for impact testing was adhered to. The specimen is 60 mm in length and 15 mm in width. An impact test with Charpy was used to examine this attribute.

2.4.3.4 Water Absorption Test

The maximum percentage of water absorption for the manufactured hybrid composite has been assessed in accordance with ASTM D570. Samples have been removed from distilled water after 24 hours of immersion and are fully submerged. The sample was then weighed after the full removal of all surface water using a dried and clean cloth. This process was repeated at exposures of 24, 48, 98, 196 and for over 312 hours (Sujon et al., 2020).

2.4.4 Statistical Analysis (ANOVA)

When comparing the means of two or more groups, the ANOVA statistical method is used to determine whether the differences are significant. The means of various samples are compared using an ANOVA to determine the influence of one or more variables on the result. The filler content in weight percent and loading speed had a considerable impact on the ANOVA for tensile stress values at the 95% confidence level. The optimal tensile stress value is reached when the filler content is 10% and the loading speed is raised. Tensile stress is increased as loading speed increases. Flexural strength reaches its peak at 10% filler content, after which it starts to drop up to 25% filler content. However, in the flexural test, both the filler weight percent and the loading speed have a substantial impact on the flexural stress value at the 95% confidence interval. Flexural strength also rises with an increase in loading speed. The ANOVA table for tensile stress and flexural stress data is displayed in Tables 2.2 (Bankoti et al., 2017) and 2.3 (Bankoti et al., 2017) below.

Table 2.2: ANOVA table for tensile stress (Bankoti et al., 2017)

Source	DF	Seq (SS)	Contribution	Adj (SS)	Adj (MS)	F-Value	P-Value
A (percentage filler wt.)	5	308.5	75.90%	308.5	61.71	29.34	0
Loading	2	76.91	18.92%	76.91	38.46	18.28	0
Error	10	21.03	5.17%	21.03	2.103		
Total	17	406.5	100.00%				

Table 2.3: ANOVA table for flexural stress (Bankoti et al., 2017)

Source	DF	Seq (SS)	Contribution	Adj (SS)	Adj (MS)	F-Value	P-Value
A (percentage filler wt.)	5	1004	62.80%	1004	200.8	57.91	0
Loading	2	560	35.04%	560	280	80.77	0
Error	10	34.67	2.17%	34.67	3.467		
Total	17	1598	100.00%				

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter is mostly concerned with the project's methodology. The process includes material preparation, ratio calculation, mechanical testing, ANOVA analysis, cost production, flow chart of sample production, and a Gantt chart. Figure 3.1 below illustrates the general procedures involved in producing samples.

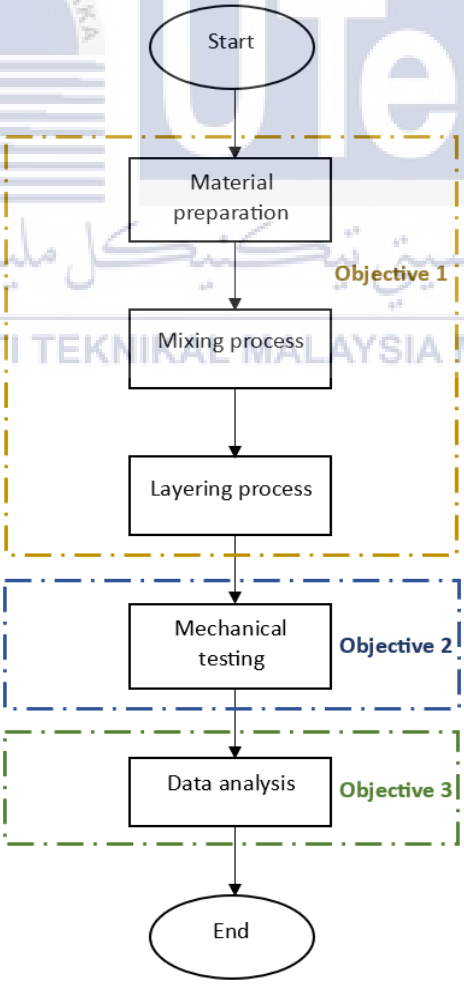


Figure 3.1: General flow chart of sample production

3.2 Sample Preparation

Three materials involved in this research are eggshells, jute fiber and polyester. The most crucial process here is the eggshells preparation where a few processes and treatments must be done to achieve the expected result. The processes involved in sample preparation are eggshell treatment, grinding process, sizing process and last but not least is the mixing and layering process.

3.2.1 Eggshell Treatment

Waste chicken eggshell first being washed to get rid of the leftover albumen and impurities adhered. Then, cleaned eggshells are soaked in clean water for 24 hours. After 24 hours, eggshells are then placed under the sun and let dry for 48 hours in order to remove the moisture content. Each process was presented in Figure 3.2 below.

a) Waste eggshells are washed

b) Cleaned eggshells are soaked in water for 24 hours.

c) Eggshells were then dried under the sun for 48 hours.

Figure 3.2: Eggshell powder preparation processes

3.2.2 Grinding and Sizing Process

Dried eggshells were then crushed manually before ground with a mechanical grinder. This process had to be done repeatedly until it achieved the desired uniform micron size. Then, the ground eggshells were sieved using a Test Sieve to obtain the average grain size. Figure 3.3 and 3.4 below shows the grinding and sizing process of eggshells.

(a) Dried eggshells are crushed manually.

(b) Crushed eggshells were ground using the mechanical grinder.

(c) The final material: eggshell powder.

Figure 3.3: Grinding Process

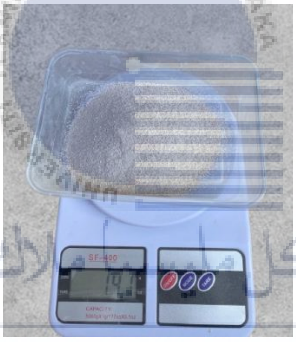
(a) Test Sieve

(b) Final size of eggshell powder: 500μm

Figure 3.4: Sizing Process

3.2.3 Mixing and Layering Process

In this process, silicon mold was used to fabricate the sample. Polyester, eggshell powder, and hardener are the ingredients that go into the mixing procedure as illustrated in Figure 3.5. Both polyester and eggshell powder were measured in accordance with the ratio, while hardener were measured with 100g to 0.3g of polyester to hardener ratio. First, weighed the polyester and harderner in a container and mix together. The eggshell powder was then weighed and thoroughly included in the previously prepared polyester and hardener combination. The layering process was then carried out by first pouring the quarter of mixture, followed by placing the jute and then poured all the mixture into a silicon mold.



(a) Weighing the eggshell powder

(b) Weighing the polyester and hardener

(c) Mixed the eggshell powder, polyester and hardener

(d) Spread out quarter of mixture

(e) Placed the jute

(f) Poured all mixture on top of jute

Figure 3.5: Weighing the eggshell powder, polyester resin, and drops of hardener

3.3 Calculation of Ratio

To determine the total use of eggshell powder (EP) and polyester from the ratio, the application of density formula (Equation 3.1) is used. Density is the mass of a material substance per unit volume.

$$\boldsymbol{\rho = \frac{m}{v}} \quad (3.1)$$

where ρ is density, m is mass, and v is volume, is the formula for density. Density makes it simple to calculate the relationship between mass and volume, as seen below. Equation 3.2 states that a body's mass is equal to its volume times its density, whereas its volume is equal to its mass divided by its density (Equation 3.3).

$$\boldsymbol{m = \rho v} \quad (3.2)$$

$$v = \frac{m}{\rho} \tag{3.3}$$

3.4 Mechanical Testing

Mechanical testing was the crucial part to analyze the mechanical as well as physical properties of the sample. All samples were cut into specimen testing according to the ASTM standards with a fixed thickness of 1.0 cm. The CNC router machine model MODELA PRO2 (MDX-540) is shown in Figure 3.6. The material test must then be placed on the vice in order to be held in place. The coordinate or position axis on the computer control panel needs to be set to zero. Following the verification of the coordinates using an NC code, the cutting tool needs to line up with the designated spot. There are spindle speeds that range from 100 rpm to 200 rpm. Pressing the "output" button on the control panel completes the cutting operation. Four tests: tensile test, impact test, flexural test, and water absorption test were conducted as follows, after the sample preparation was done.

Figure 3.6: CNC router machine model MODELA PRO2 (MDX-540)

3.4.1 Tensile Test

The specimens for the tensile test were examined using the Universal Testing Machine model Shimadzu as shown in Figure 3.7. They were prepared in accordance with the ASTM D3039 standard, featuring dimensions of 250mm in length and 25mm in width, respectively. ASTM D3039 is specifically designed for measuring continuous high-modulus reinforced polymer matrix composites or polymeric materials containing reinforcing fibers. The tensile specimen held at the grips is illustrated in Figure 3.8.

Figure 3.7: Universal Testing Machine model Shimadzu

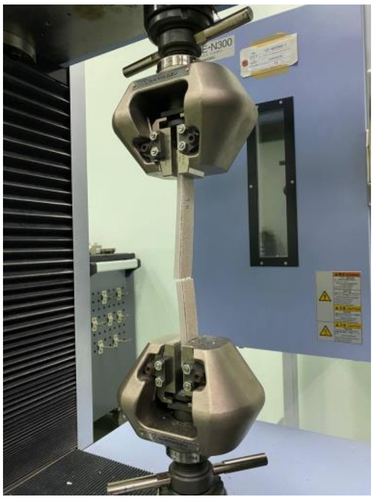


Figure 3.8: The tensile specimen held at the grips

3.4.2 Impact Test

In this study, the ASTM D6110 standard was used to measure the energy collected from standardized tests to determine the resilience of plastics to fracture by flexural shock. A pendulum system was used to measure the plastic's resistance to breaking when it was struck in a three-point bend configuration. The test were tested on Impact Tester Machine model INSTRON CEAST 9050 as depicted in Figure 3.9, was performed to figure out how much force is needed to break the specimen. The length and width of the specimen were 60mm and 15mm, respectively.

The Charpy Impact test was used for testing this property. To analyse the result data in the Charpy method, the specimen must have a V-notch. The V-notch has a diameter of 2 mm and a 45 degree angle. The ASTM E23 specimen size: 55 mm in length, 12.5 mm in breadth, and 10 mm in thickness, is used for impact testing. The impact testing results of the data were captured once the process is completed. Figure 3.10 displays the impact test specimen struck and placed on an anvil.

Figure 3.9: Impact Tester Machine model INSTRON CEAST 9050

Figure 3.10: The impact test specimen struck and placed on an anvil

3.4.3 Flexural Test

Figure 3.11 illustrates the examination of the specimens for the flexural test with the Shimadzu model Universal Testing Machine. The three-point bending test, or flexural test, was used as per ASTM D790, with the length and width of the specimens set at 250mm and 25mm, respectively.

Figure 3.11: Shimadzu model Universal Testing Machine

The specimen of eggshell powder reinforced with polyester resin is loaded horizontally in a three-point loading configuration as shown in Figure 3.12. In a 3-point bend test, the outside fibres of the sheet or plate are put under maximum stress and strain while the convex side is tensioned. Failure happens when the strain or elongation goes beyond the limits of the material. The loading nose applies force to the specimen's centre, causing three-point bending to occur at a specific rate. The loading speed, maximum deflection, and support span of this test are its parameters.

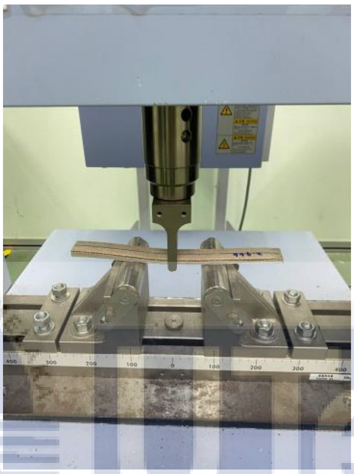


Figure 3.12: Specimen were placed horizontally in the three-point bend test

3.5 Water Absorption Test

Under the ASTM D570 standard, the maximum percentage of water absorption for the manufactured hybrid composites was examined. The samples were removed from the water after being fully submerged, and this method was repeated at various exposure times for days: 5 days, 10 days, 15 days, 20 days and 25 days. Following the complete removal of all surface water with a dry, clean cloth, the samples were then weighed. This process was repeated multiple times with various exposures.

a) All samples are submerged in water for days

b) Sample are weighed after 5 to 25 days

Figure 3.13: Procedure of water absorption test

To calculate the percentage of water absorption, the equation below was applied.

$$\textit{Water absorption}\ (\%) = \frac{m_2 - m_1}{m_1} \times 100 \qquad (3.5)$$

Where m_1 is the weight in grammes before being submerged in water, and m_2 is the weight in grammes after being submerged in water.

3.6 Statistical Analysis (ANOVA)

The study of the outcomes using statistical analysis is the last step. The eggshell powder reinforced by polyester resin yielded the best ratio based on the findings of the mechanical properties analysis. An analytical method for testing whether the averages of samples from a population are the same is called an ANOVA. To examine the energy of the EPPR (Eggshell Powder Polyester Resin) composites, a one-way analysis of variance (ANOVA) was used. By measuring the energy of EPPR composites for each of the five significant eco-friendly ratios, expanding ANOVA was used in this investigation. For choosing the optimal composition for the material, more information must be provided. Table 3.1 below shows the one-way ANOVA formula that was used.

Table 3.1: One-way ANOVA formula

Source of Variance	Degree of Freedom (df)	Sum Square (SS)	Mean Square (MS)	F-ratio
Between Groups (Treatment)	$k-1$	$SSB = \sum_{j=1}^{k}(\bar{X}_j - \bar{X})^2$	$MSB = \frac{SSB}{k-1}$	$F = \frac{MSB}{MSW}$
Within Groups (Error)	$n-k$	$SSW = \sum_{j=1}^{k}\sum_{j=1}^{l}(X - \bar{X}_j)^2$	$MSW = \frac{SSW}{n-k}$	
Total	$n-1$	$SST = \sum_{j=1}^{n}(\bar{X}_j - \bar{X})^2$		

3.7 Cost of Materials

The estimated production costs are presented as Table 3.2, Table 3.3, and Table 3.4 below.

Table 3.2: Estimated direct cost

Direct Cost			
Cost type	**Description**	**Price (RM)/month**	**Total**
Transportation	Car	50	250

Table 3.3: Estimated indirect cost

Indirect Cost			
Cost type	**Description**	**Price (RM)/month**	**Total**
Utilities	Electricity, water and internet	25	50

Table 3.4: Estimated cost of materials

Cost of Materials			
Material	**Price (RM)**	**Quantity**	**Total**
Polyester	32.90	Kilogram	65.80
Jute Fiber (114cm × 100cm)	9.60	Meter	9.60
Silicon Mould	17.72	2	35.45
Plastic Basin	5.90	2	11.80
Pail	9.50	1	9.50

Total 132.15

Total Project Cost **RM** **432.12**

3.8 Detailed Flow Chart of Sample Production

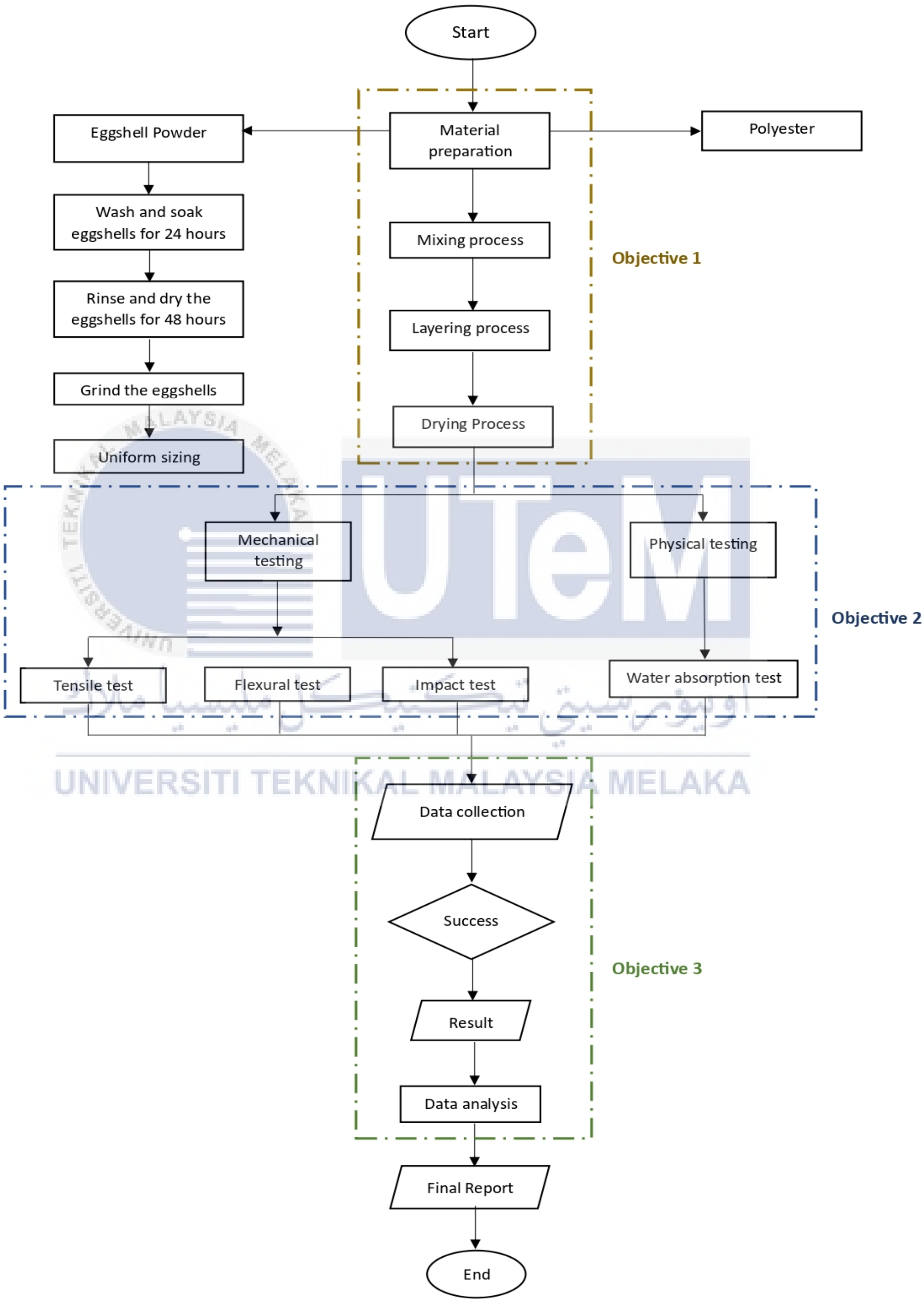


Figure 3.14: Flow chart of research

3.9 Gantt Chart

A project management tool called a Gantt chart is employed to help with project planning, scheduling, and monitoring. In addition, it can enhance the task delegation, resource allocation, planning and scheduling. A horizontal bar graph in a Gantt chart visually depicts all information. The full table of Gantt Chart can be found in Appendix A and Appendix B.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter focuses on the strength of composites. Four tests have been conducted on EPPR for each sample of ratios: tensile, impact, flexural and water absorption. The results of each test will be analyzed and justified based on the findings of all samples.

4.2 Tensile Test Result

The specimen used for the tensile test after testing is shown in Figure 4.1. The five eco-friendly Eggshell Powder Polyester Resin (EPPR) composite ratios were examined using the Universal Testing Machine with 25 total of samples.

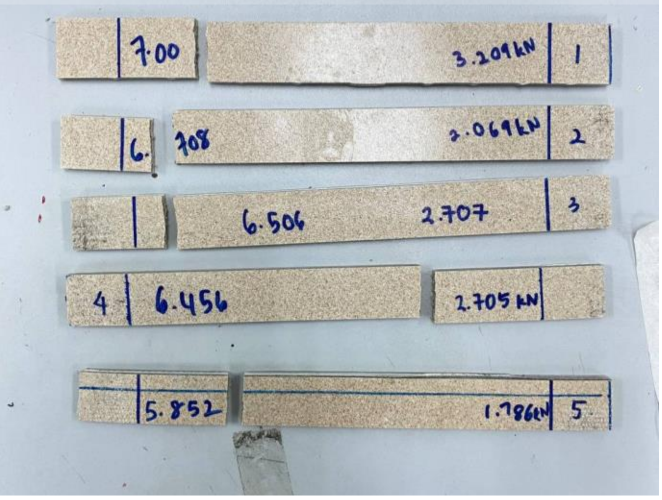


Figure 4.1: Specimen of Tensile Test

Tensile strength and elasticity data for each of the five environmentally friendly EPPR composite ratios: 20EP80PR, 40EP60PR, 50EP50PR, 60EP40PR, and 80EP20PR, are shown in Figure 4.2 and 4.3. It was discovered that 20EP80PR had more tensile strength and elasticity than the EPPR composite ratios. On the other hand, 80EP20PR exhibited the lowest values of elasticity and tensile strength. This finding implies that when the amount of eggshell powder in EPPR composites increases, the tensile strength of the environmentally friendly ratios decreases. According to research by Dorsherman et al. (1999), tensile strength and elasticity losses are caused by the filler particles clumping together and the filler matrix's poor adherence. Particulate-filled polymer composites' strength is mostly dependent on the matrix and filler's interfacial adhesion, which makes it easier for a tiny portion of stress to be transferred to the filler particle during deformation. While the decrement in tensile modulus can be interpreted as a rise in the material's resistance to deformation. This is because the composite can support heavier loads when the filler loading is higher (C.T. Ratnam et al., 2010).

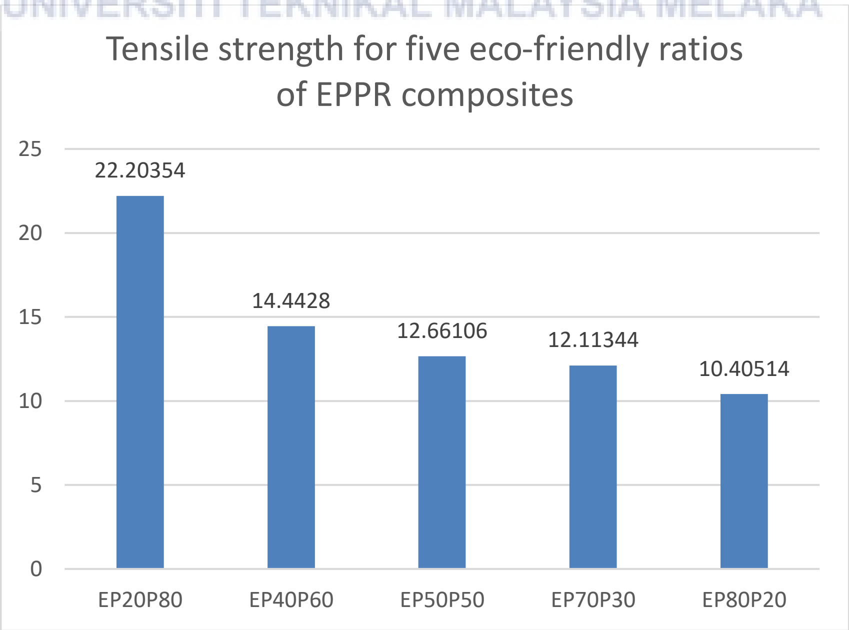


Figure 4.2: Tensile strength for five eco-friendly ratios of EPPR composites

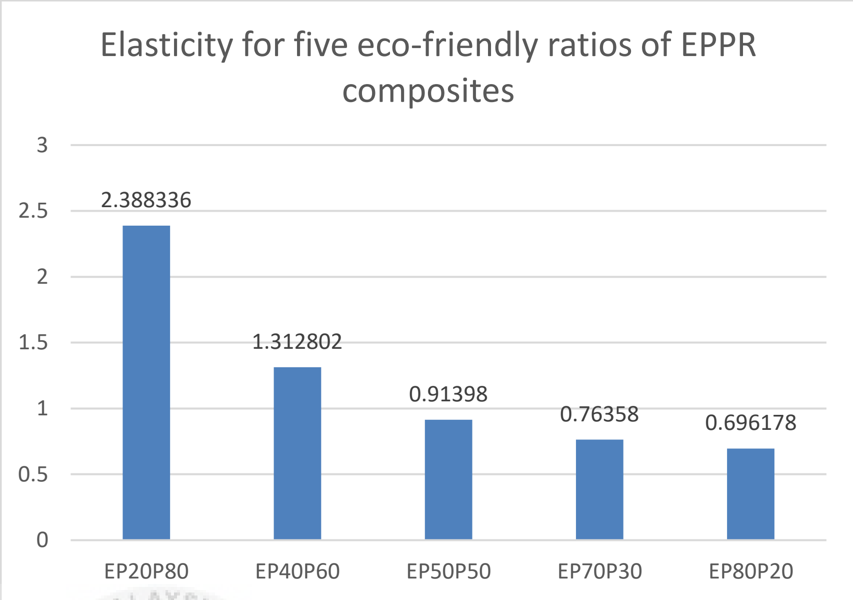


Figure 4.3: Elasticity for five eco-friendly ratios of EPPR composites

The tensile strength and elasticity of the EPPR composites, as indicated in Table 4.1 and 4.2, respectively, were examined using a one-way analysis of variance (ANOVA). The findings demonstrated that the tensile strength and elasticity of EPPR composites for each of the five eco-friendly ratios were significant, as indicated by the P-value being less than the $\alpha = 0.05$ significant cut-off threshold. Consequently, it shown that the average values of tensile strength and elasticity varied among the five environmentally acceptable ratios of EPPR composites. Therefore, mixing eggshell powder with polyester resin matrix in ratios of 20% and 80%, respectively, yields the best tensile characteristics.

Table 4.1: ANOVA of tensile strength for five eco-friendly ratios of EPPR composites

Analysis of Variance

Source	**DF**	**Seq SS**	**Contribution**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
RATIO	4	425.511	98.18%	425.511	106.378	269.87	0.000
Error	20	7.884	1.82%	7.884	0.394		
Total	24	433.395	100.00%				

Table 4.2: ANOVA of elasticity for five eco-friendly ratios of EPPR composites

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
RATIO	4	9.7493	95.25%	9.7493	2.43731	100.35	0.000
Error	20	0.4858	4.75%	0.4858	0.02429		
Total	24	10.2350	100.00%				

4.3 Impact Test Result

The specimen utilized on Impact Tester Machine model INSTRON CEAST 9050 for the impact test following testing is seen in Figure 4.4.

Figure 4.4: Specimen of Impact Test

Impact energy is shown against filler content in Figure 4.5. As predicted by Hussein et al. (2011), when the filler content rose, the eggshell gradually enhanced the polyester’s stiffness. Eggshell powder acts as a solid "plasticizer" when added to polymers, increasing their flexibility and capacity to absorb and dissipate energy. This may explain the observed increase in impact strength, as the polymers require high impact energy to fracture. The results show that the EPPR composite improves impact strength synergistically. This synergy may be attributed to the fine dispersion of the second component (eggshell), which is made possible by polyester's good viscosity match. Thus, the best impact properties are obtained by combining eggshell powder in a ratio of 80% with 20% polyester resin matrix.

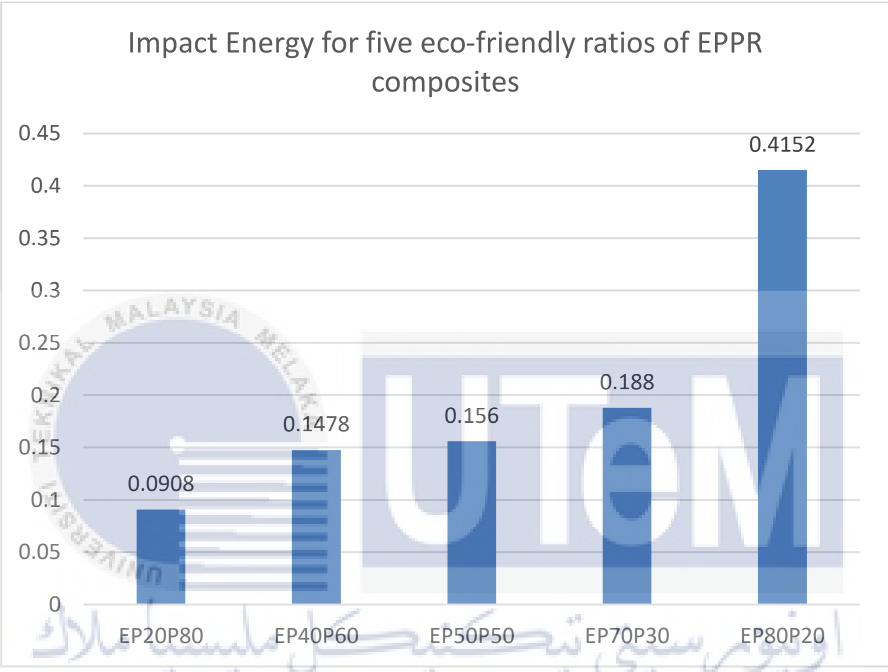


Figure 4.5: Impact Energy for five eco-friendly ratios of EPPR composites

The EPPR composites' impact energy which are shown in Table 4.3, were investigated by one-way analysis of variance (ANOVA). Given that the P-value was bigger than the $\alpha = 0.05$ significant cut-off criterion, the results showed that the impact energy composites were not significant for each of the five eco-friendly ratios. The average impact energy values across the five environmentally permitted ratios of EPPR composites were found to differ.

Table 4.3: ANOVA of impact energy for five eco-friendly ratios of EPPR composites

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
RATIO	4	0.3152	28.34%	0.3152	0.07880	1.98	0.137
Error	20	0.7968	71.66%	0.7968	0.03984		
Total	24	1.1120	100.00%				

4.4 Flexural Test Result

Figure 4.6 shows the specimen used for the flexural test after testing. There were 25 samples for each of the five environmentally friendly Eggshell Powder Polyester Resin (EPPR) composite ratios that were tested with the Universal Testing Machine: 20EP80PR, 40EP60PR, 50EP50PR, 60EP40PR, and 80EP20PR.

Figure 4.6: Specimen of Flexural Test

The five environmentally friendly EPPR composite ratios: 20EP80PR, 40EP60PR, 50EP50PR, 60EP40PR, and 80EP20PR, are displayed in Figure 4.7 with corresponding flexural strength data. Flexural strength of 20EP80PR were found to be highest than those of the EPPR composite ratios. Conversely, the flexural strength values were lowest for 80EP20PR. The tensile strength of the environmentally friendly ratios appears to decline with an increase in eggshell powder content in EPPR composites. This is because the addition of eggshell powder increases the elasticity of the material, which lowers its strength. The ability of the filler to facilitate the stress transfer from polymer filler to matrix is indicated by an increase in the elongation break with an increase in filler loading (H. R. Kricheldorf et al., 2005).

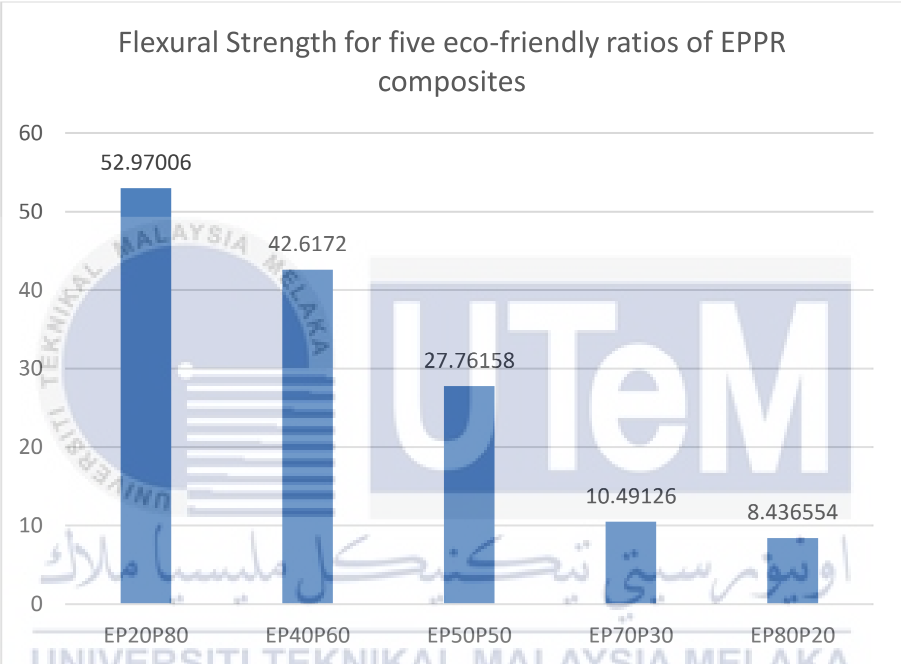


Figure 4.7: Flexural Strength for five eco-friendly ratios of EPPR composites

A one-way analysis of variance (ANOVA) was used to look at the flexural strength of the EPPR composites, which are shown in Table 4.4 The P-value was smaller than the $\alpha = 0.05$ significant cut-off criterion, indicating that the flexural strength of EPPR composites were significant for each of the five eco-friendly ratios. As a result, it showed that there were differences in the mean flexural values across the five environmentally approved EPPR composite ratios. Consequently, the best flexural properties are obtained when eggshell powder and polyester resin matrix are mixed in ratios of 20% and 80%, respectively.

Table 4.4: ANOVA of flexural strength for five eco-friendly ratios of EPPR composites

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
RATIO	4	7627.36	99.90%	7627.36	1906.84	4977.22	0.000
Error	20	7.66	0.10%	7.66	0.38		
Total	24	7635.02	100.00%				

4.5 Water Absorption Test Result

Figure 4.8 depicts all the sample being submerged in water for various exposure of time: 5 days, 10 days, 15 days, 20 days and 25 days. The samples underwent removal from the water after complete submersion, and this procedure was replicated at different time intervals in hours. After eliminating all surface water using a dry, clean cloth, the samples were subsequently weighed. This sequence of steps was repeated several times with varying exposure durations.

Figure 4.8: Samples being submerged in water for days

The variation of the water absorption ratio versus exposure duration for EPPR composite is displayed in Figure 4.9. The graphic illustrates how composites with greater filler content exhibit greater water absorption. According to research by Hussein, A. A

(2011), this is because composites with higher filler contents have a greater capacity to absorb water. Because it becomes more difficult to achieve a homogenous dispersion of filler with high filler concentration, clumping together tends to form more frequently as filler quantity increases. The filler in composites clumps together, increasing the composites' absorption of water.

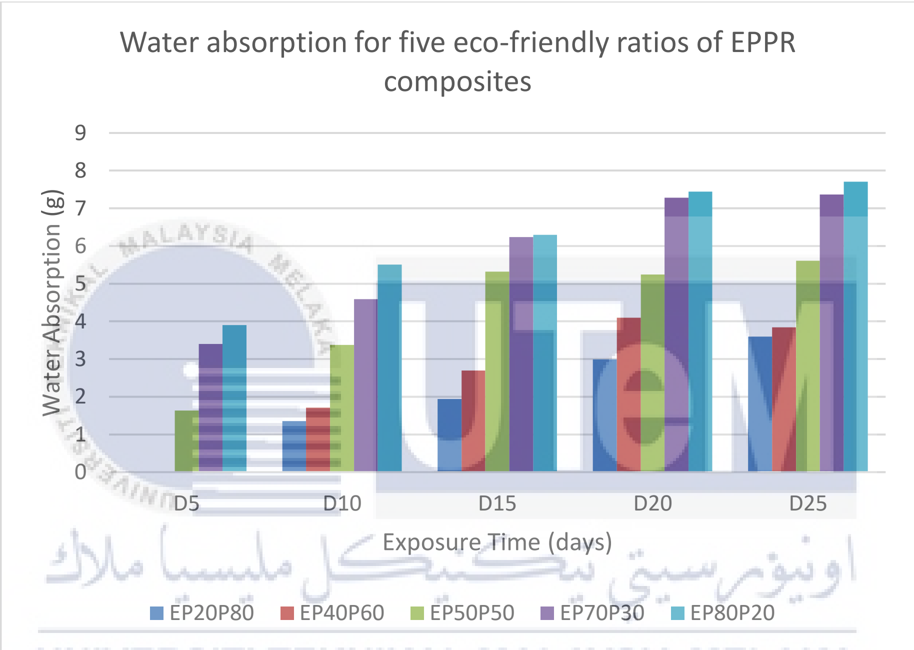


Figure 4.9: Water absorption for five eco-friendly ratios of EPPR composites

The tables below present the outcomes of a one-way analysis of variance (ANOVA) performed to assess the water absorption of the EPPR composites. As depicted in Table 4.5, the water absorption exhibited significance in five-days exposure as the P-value fell below $\alpha = 0.05$. However, Tables 4.6, 4.7, 4.8 and 4.9 for subsequent exposures (10 days, 15 days, 20 days, and 25 days), the P-values exceeded the $\alpha = 0.05$ significance threshold, indicating nonsignificant differences. Notably, the water absorption values across the five environmentally permitted ratios of EPPR composites were found to differ.

Table 4.5: ANOVA of water absoption after five-day exposure

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Ratio	4	97.15	51.27%	97.15	24.287	5.26	0.005
Error	20	92.35	48.73%	92.35	4.618		
Total	24	189.50	100.00%				

Table 4.6: ANOVA of water absoption after ten-day exposure

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Ratio	4	64.27	15.10%	64.27	16.07	0.89	0.488
Error	20	361.35	84.90%	361.35	18.07		
Total	24	425.62	100.00%				

Table 4.7: ANOVA of water absoption after fifteen-day exposure

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Ratio	4	83.77	18.26%	83.77	20.94	1.12	0.376
Error	20	374.90	81.74%	374.90	18.75		
Total	24	458.67	100.00%				

Table 4.8: ANOVA of water absoption after twenty-day exposure

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Ratio	4	76.18	14.45%	76.18	19.04	0.84	0.513
Error	20	450.91	85.55%	450.91	22.55		
Total	24	527.09	100.00%				

Table 4.9: ANOVA of water absoption after twenty-five-day exposure

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Ratio	4	73.26	17.13%	73.26	18.31	1.03	0.414
Error	20	354.43	82.87%	354.43	17.72		
Total	24	427.69	100.00%				

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

A study on the mechanical properties of a jute fiber polyester hybrid composite filled with eggshell was conducted following the chosen methods. Concluding the exploration of the eggshell-filled jute-polyester composite, each objective has played a crucial role in unraveling the material's mechanical properties.

5.1.1 Objective 1: To fabricate an eggshell-filled, hybrid jute-polyester composite

The research aimed to create a composite material by combining jute fibers, polyester, and eggshell powder. The fabrication process employed intricate layering techniques, and the resulting material was meticulously cut into specimen tests. These specimens were then carefully prepared to ensure uniformity and consistency, laying the groundwork for a comprehensive evaluation of the material's mechanical properties through various testing procedures. This deliberate approach in sample preparation is crucial to obtaining reliable and meaningful data during subsequent mechanical testing.

5.1.2 Objective 2: To analyze the mechanical properties of fabricated materials using tensile, flexural, and impact tests

Mechanical properties of the fabricated composite (EPPR) were assessed through standardized tests, including tensile, flexural, and impact tests, following ASTM standards.

The study provided insights into the composite's performance under various conditions where it revealed that the incorporation of eggshell powder influenced the mechanical properties, with specific ratios demonstrating optimal results in tensile strength, elasticity, flexural strength, impact strength, and water absorption. The results showed that the ratio of 20EP80PR yields the best in tensile strength, elasticity and flexural strength, while 80EP20PR yields best in impact strength and water absorption.

5.1.3 Objective 3: To identify the statistically significant differences on various reinforced composite ratios

At the end of this research, the statistical significance of differences among various environmentally friendly ratios of the composite were investigated through one-way ANOVA analysis. This approach allowed for a rigorous examination of how different ratios impacted the mechanical properties, providing robust insights into the optimal composition for enhanced performance. The significance threshold was set at $\alpha = 0.05$, and P-values were obtained as the outcome of this analysis. The data for tensile and flexural tests are significant, while the impact and water absorption tests are not significant.

5.2 Contribution

The project makes a notable contribution to the field of composite materials by successfully incorporating eggshell powder into a hybrid jute-polyester composite. This innovative approach not only enhances the mechanical properties of the composite but also promotes environmental sustainability by utilizing a natural waste product. The detailed analysis, supported by statistical methods such as one-way ANOVA, provides valuable insights into the optimal composite ratios for specific mechanical properties. This research contributes to the development of eco-friendly materials with improved performance characteristics, offering potential applications in various industries seeking sustainable solutions.

5.3 Limitation

Despite the valuable insights gained from this research, certain limitations should be acknowledged. The study primarily focused on mechanical properties, and while these provide a comprehensive understanding of the composite material, other aspects such as long-term durability or environmental impact were not extensively explored. Additionally, the study conducted tests under controlled laboratory conditions, and the real-world performance of the composite in varied environmental conditions remains to be fully addressed. These limitations highlight opportunities for future research and development in the refinement and broader application of the fabricated composite material.

5.4 Recommendation

Numerous suggestions can be proposed for implementation in future research endeavors.

1) Utilize advanced characterization techniques like scanning electron microscopy (SEM) or X-ray diffraction to delve into the microstructural alterations resulting from the inclusion of eggshell powder. This will offer a more comprehensive understanding of the material's behavior.

2) Investigate the practical applications of the developed EPPR composite in specific industries or products.

3) Examine various processing methods for eggshell powder, including adjustments to particle size or surface treatment, to evaluate their impact on the mechanical properties and overall performance of the composite material.

4) Investigate the influence of filler size on the thermal properties of the composite film.

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