Degradation and Characterization of Bio-Waste Reinforced Polymer Composite

by

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CERTIFICATION OF APPROVAL

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Mechanical Engineering Programme
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Approved by,

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January 2020

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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ABSTRACT

In this study the degradation and mechanical characteristics of the bio-waste composites will be studied. The bio-waste composite used in this instance is the watermelon rind (WR) with polypropylene (PP). The WR is first collected and washed to fabricate the composite. After that, it is dried in a drying oven under the temperature of 60˚C for 18 hours to remove all moisture. The dried WR are then grinded in a mortar grinder to turn it into a fine powder. The composite is then put through an extruder where it is blended well and composites of10% and 20% of WR as filler in PP (10WR/90PP and 20WR/80PP) are produced. The composite will be subjected to immersion into two different solutions namely tap water and seawater. The percentage of moisture absorbed at time intervals of 24 hours for a total time of 168 hours is recorded. The increase in weight percentage of WR powder from 10% to 20% used correlates to a more exponential increase in the amount of moisture absorbed over a period of 24 hours. The composite immersed in the seawater absorbs more moisture than the same composite immersed in the tap water up to the 48 hours mark.

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CHAPTER 1

INTRODUTION

1.1 Background of study

In the current day and age, the effect of our human activities on the earth has never been more prevalent. A World Bank report extends that the measure of solid waste we create on earth will twofold continuously until 2025 and if current patterns proceed, we are probably going to go from 3.5 million tons to 6 million tons for each day by that point [1].

If these trends continue, we will most definitely be dealing with a monstrous waste management problem. This is already evident around the world by news of insufficient landfills as well as landfills being overfilled. Now, according to a new report from the Solid Waste Environmental Excellence Protocol (SWEEP), the 2,000 active sites in America storing most of this waste are now approaching their capacity [2]. In Malaysia, SWCorp deputy chief executive officer (technical) Dr Mohd Pauze Mohamad Taha said that in 2018, Malaysians generated 38,142 tonnes of garbage, which is double the amount Malaysians produced in 18,000 tonnes [3]. According to Prof Dr P. Agamuthu, Malaysia's landfills are nearly full, this in turn causes many illegal landfills to be developed which are often unsanitary and cause more harm due to improper handling of the waste[4]. Mr Ho De Leong, chairman of Waste Management Association said that there are classifications used to grade whether landfills are considered to be sanitary based on the way the waste is handled[4]. He further stated that there are very few landfills in Malaysia which have been rated as sanitary[4].

Food wastage is also an enormous problem in Malaysia. Statistics by SWCorp Malaysia indicate that citizens normally produce up to 38,000 tonnes of waste per day. From that enormous amount, 15,000 tonnes are made up of food waste, 60% of which are actually avoidable food waste, meaning food disposed which is still edible for example bread crusts, fruits and such[5]. According to Institute of Islamic Understanding Malaysia (IKIM)'s centre for Science and Environment Studies' Fellow Azrina Sobian, contrary to normal belief, households actually produce the largest amount of food wastage at 38%, even more than wet markets (24%), restaurants (23%) or hotels (7%)[6]. This represents an enormous wastage as these materials can actually still be consumed or used for other purposes.

Therefore, it is paramount that we as inhabitants of the planet take huge steps to reduce our waste production footprint on the earth. Methods like the 3Rs (Reduce, Reuse, Recycle) and the production of bio-degradable materials have been put forth and carried out. Governments all over the world have carried out various activities to control the amount of waste their population produce. Efforts like providing recycle bins all over cities and incentives for people who recycle is very common in this day and age.

This waste crisis has incentivised scientists to pay attention to bio-waste polymer composites, through the usage of the otherwise disposed-of waste items, scientist have been able to not only combat the existing waste problems but able to produce materials which greatly surpass the ability of existing materials. The different organic waste, including jute, coir, sisal, pineapple, ramie, bamboo and banana, is now used to strengthen the plastic composite [7].

1.2 Problem Statement

In recent years, bio-waste reinforced polymer composites have attracted considerable attention and interest from materials scientists and engineers because the composites combine superior mechanical property, dielectric property and environmental benefits such as renewability and biodegradability [8]. Waste problems have also provided an increased incentive for the production of bio-waste reinforced polymer composite materials because they enable a good alternative usage of waste materials, especially food waste, which would otherwise end up in landfills.

Through the production of a bio-waste reinforced composite namely, the combination of the PP with the watermelon rind(WR), this study aims to study the degradation characteristics of the WR/PP composite. Two composites, 10% Watermelon Rind/90% PP (10WR/90PP) and 20% Watermelon Rind/80% PP(20WR/80PP), are immersed in different solutions namely the tap water and the seawater. Moreover, it also aims to compare the degradation characteristics of the Watermelon Rind(WR)/Polypropylene(PP) composite against the 100% PP(100PP) polymer.

1.3 Objectives

The objective of our study is as follows:

i. to develop a bio-waste composites made from polypropylene (PP) and leftover watermelon rind (WR) of 10WR/90PP and 20WR/80PP
ii. to study and compare the effect of degradation test on the WR/PP composites
iii. to compare the diffusion coefficient of the WR/PP composites when immersed in tap water and seawater as well as pure PP plastic

1.4 Scope of Study

The study carried out will investigate the degradation characterization of bio-waste reinforced polymer composites.

We will first produce a composite of the bio-waste reinforced composite, in this case watermelon rind (WR), and polypropylene (PP). Then, this bio-waste reinforced polymer composite sample will be tested with the degradation test. The composites of 10WR/90PP and 20WR/80PP will be immersed in two solutions namely tap water and seawater. This is to evaluate and compare the degradation characteristics of the two different composites with immersed in the solutions. The degradation characteristics of the WR/PP composites are also compared against a 100PP polymer immersed in distilled water.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

The topic being investigated in this study is "Degradation and mechanical characterization of bio-waste reinforced polymer composites". Solid waste disposal is the biggest challenge for the governments in developing countries from both small and large cities [9]. Annually, nations produce 1.3 billion tons of garbage. This statistic is predicted to rise to 4 billion tons by 2100, according to Ede Ijjasz-Vasquez, senior director of The World Bank [10]. Landfills all over the world are becoming full. In 2016 , people produced 2,01 billion tons of solid waste, which could increase to 3.4 billion tons in 2050 [11]. Some countries have even resorted to smuggling their garbage in containers out of their country, as experienced by the maggot-infested rubbish found in a container sent to Port Klang [11]. Between January and November last year, about 5.8 million tons of trash were exported, driven by shipments from the United States, Japan and Germany [12]. Canada agreed to pay for the return of 69 vans of waste sent to the Philippines six years ago after President Rodrigo Duterte threatened to dump it in Canadian waters [13]. Therefore, compliant to the three 3R's of Reuse, Reduce and Recycle, the characteristics of these bio-waste materials should be further investigated to uncover further potential uses for them.

Bio-waste is defined as waste (such as manure, sawdust, or food scraps) that is composed chiefly of organic matter [14]. Bio-waste materials usually are biodegradable when disposed of. However, these materials still need to be placed somewhere to be allowed to decompose. Therefore, they are normally dumped in landfills to decompose. This brings forth further problems like ground water contamination as well as the release of harmful greenhouse gasses into the air. When accumulated in the landfill, the bio-waste will begin to rot. This rotting sometimes causes toxic chemicals to form and when rain falls they begin to seep into the groundwater below the landfill. High levels of toxic materials such as toxic metals, ammonia, and toxic waste as well as germs are also found at the bottom of these landfill sites due to the water that flows through the waste [15]. This mixture usually creates a high biological oxygen demand over time, which means that it can quickly de-oxygenate water [15].

This means the oxygen content in the water will drop to dangerously low levels and if this toxic water reaches lakes it may cause the death of all the river life. In terms of air pollution, the rotting waste items in the landfills produce a gas called the Landfill Gas (LFG). LFG comprise approximately 50% methane, 50% carbon dioxide (CO^2), and a small quantity of non-methane organic compounds [16]. Methane is a powerful greenhouse gas 28 to 36 times more efficient than CO^2 at trapping heat in the atmosphere over a 100-year period [16]. Fruits are considered to be one of the largest bio-waste sources present. Watermelons are one of the most widely consumed fruits all over the world. With a planting area of over 30 million mu (about 2 million hectares) and an annual output value of more than 2 trillion yuan (about $290.8 billion), China tops the world in both watermelon production and consumption [17]. Therefore, since watermelon rinds (WR) are not consumable they are often disposed of. A natural source and rich in non-essential amino acid citrulline, the WR (a common agricultural by product) contains abundant carboxylic and amino groups [18]. The characteristic of the WR is studies have shown WR consist of pectin, cellulose, proteins, and carotenoids [19]. Watermelon biomass may be classified into three major components, flesh, seed and rind. Flesh makes up around 68% of the overall weight, rind about 30% and seed around 2% of the overall weight [20]. The rind is usually discarded, used as a feed or fertilizer [20]. The WR is used as the bio-waste material in this study due to its wide consumption.

According to Dictionary.com, the word polymer means a compound of high molecular weight derived either by the addition of many smaller molecules [21]. A very common polymer used is plastics. There are many different types of plastics the most prominent ones are as follows Acrylic or Polymethyl Methacrylate (PMMA), Polycarbonate (PC), Polyethylene (PE), Polypropylene (PP), Polyethylene Terephthalate (PETE or PET), Polyvinyl Chloride (PVC) and Acrylonitrile-Butadiene-Styrene (ABS) [22]. There are seven kinds of plastics, but in Malaysia, three kinds of plastic recycling is practical [23]. PP plastics are one of the most widely used plastics around the world. PP is a thermoplastic instead of a thermoset making it recyclable. Fibres made from PP are often used in the manufacturing of clothes, a moisture barrier used for packaging items and as a plastic for Tupperware and such. One of the reasons why PP is widely used is due to the fact that it is easily obtainable and is relatively cheap when compared to other similar application plastics. PP is often used for injection moulding because of its easily mouldable characteristic. PP being a thermoplastic can be heated to melting point to become a liquid which can then be shaped easily. It also does not degrade significantly during this process of heating and cooling as opposed to its thermoset counterparts. Thermoset materials in contrast would burn instead of melting making it an unfavourable material for recycling.

PP have many favourable characteristics. PP are known to have a very good chemical resistance meaning that they do not react readily when coming into contact with acids and bases. This makes it a suitable option to contain soaps, dish washers as well as first-aid products. PP is also known to be a very tough material as it has a high ability to deform plastically without breaking. PP is also highly impermeable, doesn't allow water to penetrate its surface. This property is especially useful for applications requiring total immersion of items. PP is also often used in electrical components due to its high resistance to electricity. On the other hand, PP does also have its drawbacks. PP is very prone to damage by UV light. PP is also quite sensitive to oxidation. PP has a melting point of 160 to 166 °C, this high temperature allows it to be used for various applications in contact with heat. PP has a density of 0.936 to 0.946 g/cm^3. Due to its favourable characteristics, PP is chosen as the polymer in this experiment.[24]

The bio-waste composite used is the WR/PP polymer composite. In order to produce the bio-waste composite, first the WR is to be dried to remove all moisture. After that it is mixed with PP pallets and extruded with a screw extruder with to produce a composite. The moisture absorbent properties of the specimen after the immersion at specified time will be analysed and discussed [25]. The bio-waste composite will also be subjected to degradation test to show the degradation characteristics of the composite. The composite will be placed in two different liquid namely, tap water and seawater. The observation and percentage of moisture absorbed will be recorded over a period of 168 hours at intervals of 24 hours.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Gantt chart

The Gantt chart in Table 3.1 and Table 3.2, indicates the plan of activities to be done over the course of two semesters for both FYP 1 and FYP 2.

Table 3.1: Plan of activities to be conducted for FYP 1

FYP 1

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project	■	■												
2	Preliminary Research work			■	■	■	■								
3	Submission of Progress Assessment 1						■	■							
4	Proposal Defence								■						
5	Submission of Interim Draft Report									■	■	■			
6	Submission of Progress Assessment 2												■		
7	Submission of Interim Report												■		

Table 3.2: Plan of activities to be conducted for FYP 2

FYP2

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Lab work Starts Bio-waste Composite is prepared	■	■												
2	Tensile Test/ Hardness Test			■											
3	Morphology and Chemical Test				■										
4	Degradation Test					■	■								
5	Thermal Test				■										
6	Submission of Progress Report 1							■	■						
7	Submission of Draft Dissertation									■					
8	Viva										■	■			
9	Submission of Progress Report 2												■		
10	Submission of Project Dissertation												■		

3.2 Formation of Watermelon Rind/PP composite

3.2.1 Properties of PP

The PP pallets purchased were from LOTTE Chemical TITAN. The properties of the PP pallets are as shown in Table 3.3:-

Table 3.3: Chemical properties of the PP plastic

TYPICAL RESIN PROPERTIES [a]	UNIT	TITANPRO 6331	ASTM METHOD [b]
Melt Flow Rate, at 230°C	g/10 min	**14**	D1238
Density	g/cm³	**0.9**	D1505
Tensile Strength at Yield	kg/cm²	**360**	D638
Elongation at Yield	%	**10**	D638
Flexural Modulus	kg/cm²	**17500**	D790B
Notched Izod Impact Strength at 23°C	kg·cm/cm	**2.6**	D256A
Heat Deflection Temperature at 4.6 kg/cm²	°C	**99**	D648
Rockwell Hardness	R scale	**97**	D785A
Water absorption after 24 hours	%	**0.02**	D570

3.2.2 Preparation of Watermelon Rind (WR)/PP composite

In order to produce the WR and PP bio-waste composite. Firstly, the WR are dried and then grinded into smaller particles. The PP pallets are obtained from LOTTE Chemical TITAN. The two materials are then put through and extruder. The material that exits the extruder is in a pallet form. This material is actually the formed bio-waste composite of the WR as well as the plastic. The percentage of the WR to be used for the WR and PP was calculated using the Eq.3.1.

$$\%\ of\ watermelon\ rind\ composite = \frac{Mass\ of\ watermelon\ rind\ powder}{Total\ mass\ of\ watermelon\ rind\ powder + PP\ pallets}\ x\ 100\% \quad (3.1)$$

After measuring and mixing the correct proportion of WR and PP to be used, the mixture is extruded using the Leistritz Extruder as shown in Figure 3.1.

Figure 3.1: Leistriz Extruder

This machine is found at:

1) Extruder
    - Block 17, Mechanical Engineering, UTP

3.3 Testing of the Bio-waste composite

3.3.1 Degradation test

The degradation test is conducted in order to determine the amount of moisture that can be absorbed by a solution within specific parameters. Based on ASTM D570, six specimens of 10WR/90PP composite and six specimens of 20WR/80PP composite is tied up in a nylon cloth is made. Two solutions namely the seawater and tap water solutions are prepared. The seawater solution is made at home by missing 35g of salt with 975ml of tap water [26]. Three of each of the two composites are immersed in the tap water and a further three of the two composites are immersed in the seawater.

The specimens are then removed every 24 hours and weighed on a digital scale. The weight average of the 20WR/80PP composites are calculated using Eq.3.2, where W1, W2 and W3 is the weight of each of the specimen and W is the average weight of each of the specimen.

$$\frac{W1+W2+W3}{3} = W \qquad (3.2)$$

Then, the percentage of moisture absorbed is calculated using the Eq.3.3, where W* is the average weight of the specimen on a particular day and W is the original weight of the specimen.

$$\% \text{ Absorbtion} = \frac{W^{*}-W}{W} x100 \qquad (3.3)$$

This step is repeated for all of the specimens for a period of 168 hours (7 days). A graph of % water absorbed vs Surd hours is drawn.

3.4 Methodology Flowchart

The Figure 3.2 shows the flow of experiments to be conducted for the study

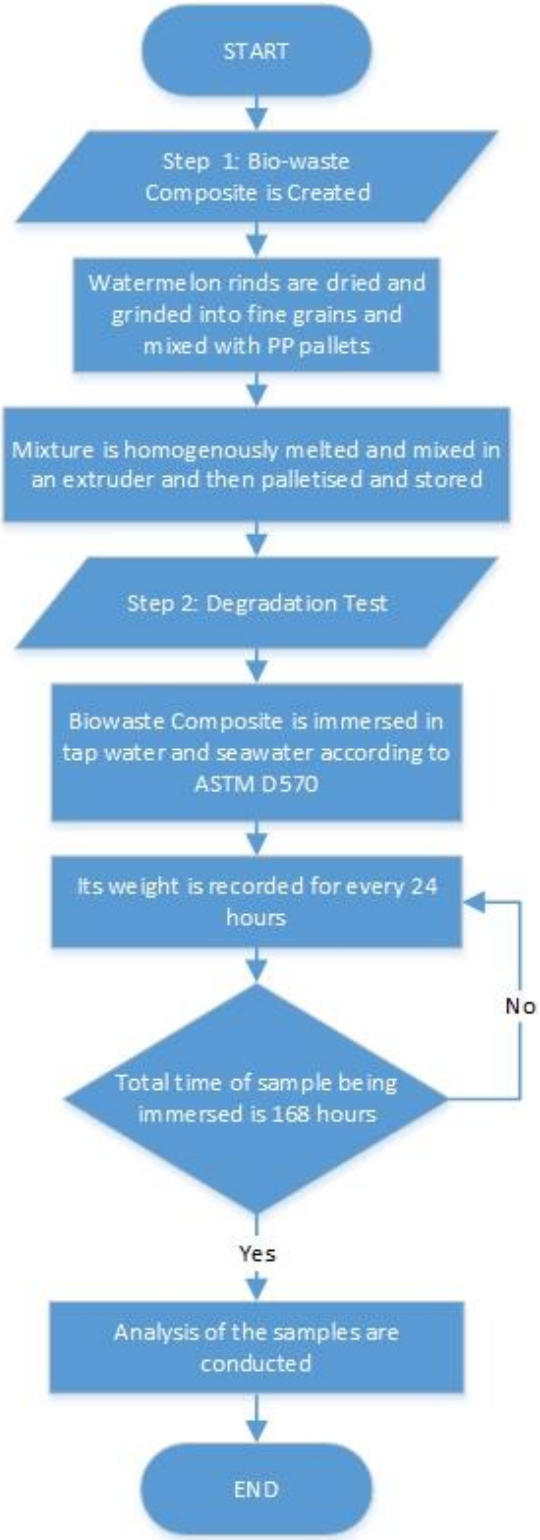

Figure 3.2: Flow of experiments to be conducted during the study

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Preparation of Watermelon Rind (WR)

The WR was produced by the following process. First the WRs were collected from a fruit shop nearby Tronoh. Then the fruits were cut, washed and arranged inside a container. The fruits are arranged in the container as shown in Figure 4.1.

Figure 4.1: Watermelons after being cut and washed

Then the fruits were dried in a drying oven under 60˚c for 18 hours to remove all moisture within the WRs. The WRs were arranged in the drying oven as shown in Figure 4.2. The appearance of the WRs after the drying as shown in the Figure 4.3.

Figure 4.2: Watermelons placed in the drying oven

Figure 4.3: Watermelons after being dried

After the drying process was complete, the watermelon rinds were then grinded using a mortar grinder and sieved to fine particles. The grinded WRs were stored as shown in Figure 4.4.

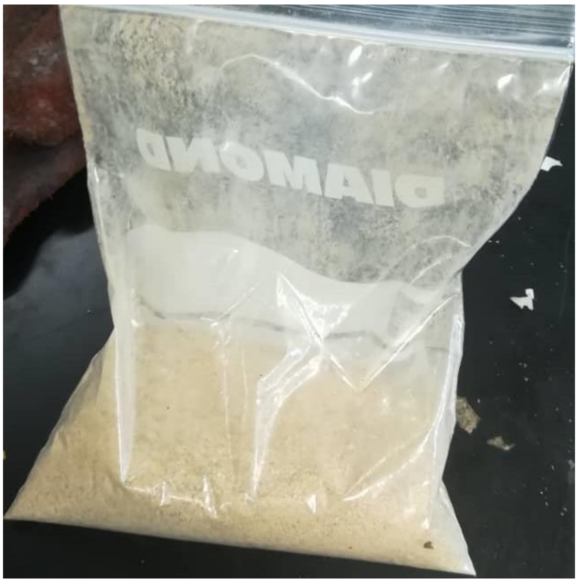

Figure 4.4: Grinded watermelon rinds

The WR and PP were then mixed proportionally with a weight percentage of 10WR/90PP and 20WR/80PP. The mixture was then put through an extruder. The extruded material was ten palletised and stored as shown in Figure 4.5.

Figure 4.5: Extruded Watermelon Rinds/PP composite

4.2 Degradation test

The degradation test was carried out to determine the amount of water that can be absorbed by the different concentrations of WR and the PP. A nylon cloth was first cut into 10cm x 10cm squares. After that 20g of watermelon rind pallet is weighed and placed on the cut squares as shown in Figure 4.6.

Figure 4.6: Watermelon rind placed on the nylon cloth and weighed

After that the squares are tied and weighed as shown in Figure 4.7. After that the tied squares with different concentrations of WRs are immersed in two solutions namely the seawater solution and the tap water. The initial weight reading of the square is weighed and recorded. The squares are left in the solution for 168 hours as shown in Figure 4.8. The weight reading of the specimen is collected every 24 hours.

Figure 4.7: Tied Watermelon Rinds(WR)/PP composite specimen

Figure 4.8: 10% and 20% Watermelon Rinds(WR)/PP specimens after being immersed in the watermelon and seawater solutions

The weight readings of each of the specimens are recorded at intervals of 24 hours for a total time of 168 hours as shown in Table 4.1. The weight values from the three 10WR/90PP specimens immersed in the tap water and seawater are averaged for each time interval as shown in Table 4.2. This is repeated for the three 20WR/80PP specimens immersed in tap water followed by the 10WR/90PP and 20WR/80PP immersed in seawater as shown in Table 4.2. The bar chart in Figure 4.9 indicates the difference in increase of the mass of each specimen at the different time intervals

Table 4.1: Weight reading of each specimen at different times

Time (Hr)	Tap Water						Seawater					
	10WR/90PP			20WR/80PP			10WR/90PP			20WR/80PP		
	Specimen No			Specimen No			Specimen No			Specimen No		
	1(g)	2(g)	3g)	1(g)	2(g)	3(g)	1(g)	2(g)	3(g)	1(g)	2(g)	3(g)
0	20	20	20	20	20	20	20	20	20	20	20	20
24	24	24	25	24	25	25	25	25	24	25	26	25
48	27	27	27	27	27	28	28	27	29	28	28	27
72	27	28	28	27	29	29	28	28	29	28	28	28
96	29	30	30	28	29	29	29	29	29	29	29	29
120	30	31	31	28	29	29	29	29	29	29	30	30
144	31	31	31	29	30	30	30	30	29	29	31	30
168	31	31	31	29	30	30	30	30	29	29	31	30

Table 4.2: Average weight reading of the specimen at different times

Time (Hr)	Tap Water		Seawater	
	10WR/90PP	20WR/80PP	10WR/90PP	20WR/80PP
	Average mass(g)	Average mass(g)	Average mass(g)	Average mass(g)
0	20.00	20.00	20.00	20.00
24	24.33	24.67	24.67	25.33
48	27.00	27.33	28.00	27.67
72	27.67	28.33	28.33	28.00
96	29.67	28.67	29.00	29.00
120	30.67	28.67	29.00	29.67
144	31.00	29.67	29.67	30.00
168	31.00	29.67	29.67	30.00

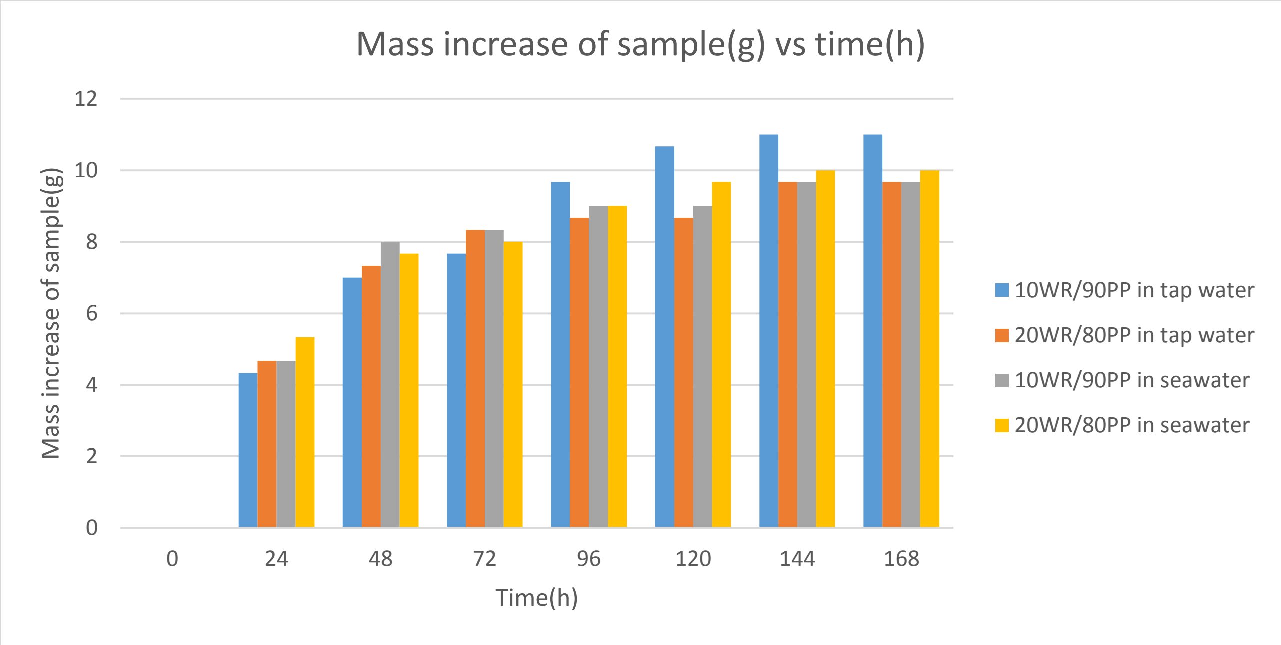

Figure 4.9: Graph of mass increase of sample (g) vs the time (h)

Table 4.3: Percentage of moisture absorbed of each of the specimens

Time (Hr)	Tap Water		Seawater		Distilled Water [27]
	10% Watermelon Rind / 90% PP	20% Watermelon Rind / 80% PP	10% Watermelon Rind / 90% PP	20% Watermelon Rind / 80% PP	100% PP
	Moisture Content (%)	Moisture Content (%)	Moisture Content (%)	Moisture Content (%)	Moisture Content (%)
0	0	0	0	0	0
24	21.65	23.35	23.35	26.65	3.30
48	35.00	36.65	40.00	38.35	3.60
72	38.35	41.65	41.65	40.00	3.70
96	48.35	43.35	45.00	45.00	3.75
120	53.35	43.35	45.00	48.35	3.80
144	55.00	48.35	48.35	50.00	3.90
168	55.00	48.35	48.35	50.00	4.00

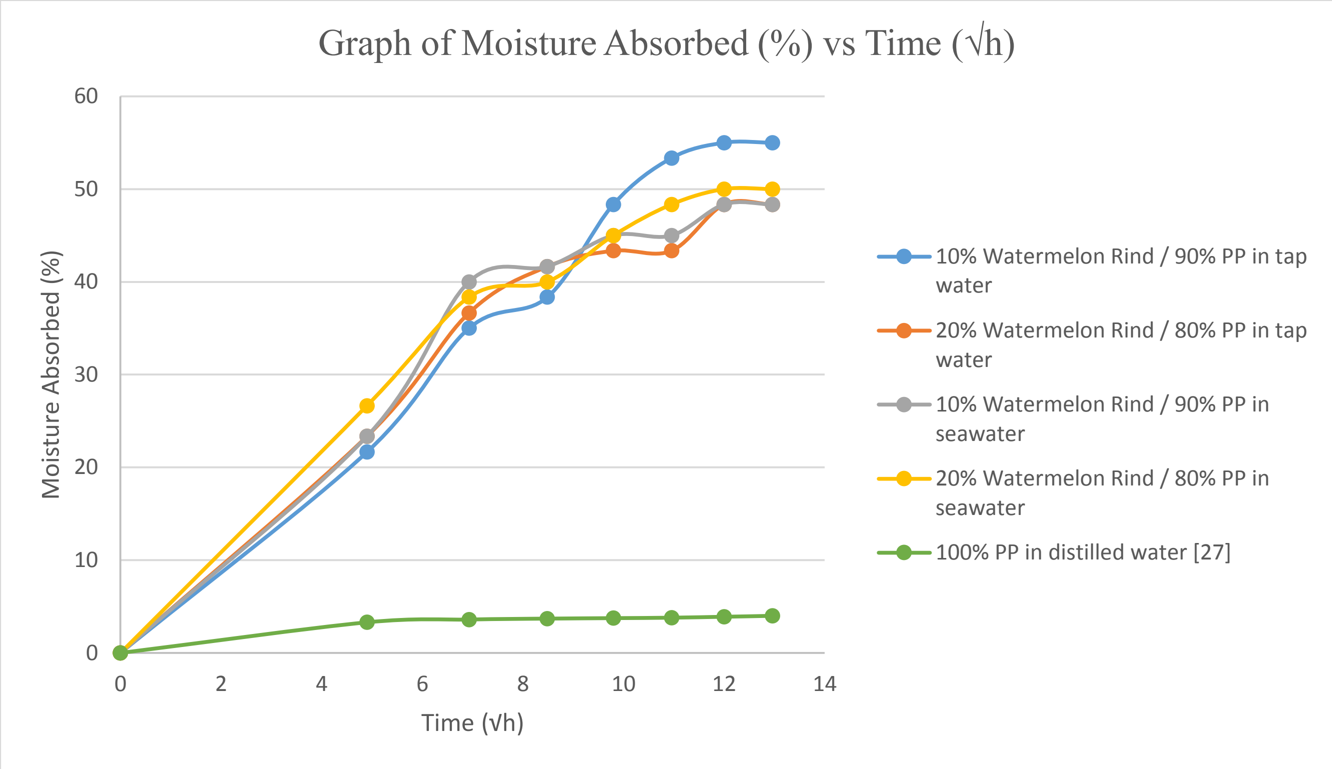

Figure 4.10: Graph of Moisture Absorbed (%) to Time (√h)

The data for the moisture absorption was obtained from a journal investigating the water absorption behaviour for polypropylene [27]. From the Figure 4.10 and Table 4.3, it can be observed that the moisture absorption continues steadily up to 144 hours or 6 days. The percentage of moisture absorbed increases more rapidly in the 20WR/80PP compared to the 10WR/90PP in both the tap water as well as the seawater. For example, after 24 hours, the percentage of moisture absorbed was higher in the 20WR/80PP composite both the seawater and tap water. The 20WR/80PP absorbed 1.7% more moisture in the tap water and 3.3% more moisture in the seawater compare to the 10WR/90PP composite. The behaviour of rapid moisture absorption behaviour of the WR/PP composite closely correlates with that of the other food materials. These food materials include, for example, the African Breadfruit (Treculia africana) seeds[28] and the Obatanpa and Mamaba Maize Hybrids (Zea mays) [29].

The rate of moisture being absorbed occurs faster in the seawater as opposed to the tap water for both composites up to 48 hours. For example, after 48 hours, the amount of moisture absorbed by the 10WR/90PP immersed in the seawater is 5% higher than the same composite immersed in the tap water. The 20WR/80PP composite immersed in seawater is 1.7% higher than the same composite immersed in the tap water after 48 hours.

The highest final average moisture absorption was recorded in the 10WR/90PP immersed in the tap water, followed by the 20WR/80PP immersed in the seawater, and finally the 10WR/90PP immersed in the seawater and the 20WR/80PP immersed in the tap water which were tied at 48.35%. The final moisture percentage absorbed by both the composites at a minimum of 48.35% also greatly eclipse the moisture absorbed by the pure PP material which recorded a maximum percentage of 4% after 168 hours.

4.2.1 Diffusion coefficient (D)

The moisture absorption characteristic can be further analysed using the diffusion coefficient equation (D) as shown in Eq.4.1, where k is the gradient of the moisture absorbed (%) to √time (√h) graph, M_m (%) is the maximum mass gain and h(mm) is the thickness of the composite[30].

$$D = \pi(\frac{kh}{4Mm})^2 \qquad (4.1)$$

Table 4.4: Diffusion coefficient and the maximum moisture content of the WR/PP composites in tap water and seawater

Parameters	Conditions			
	Tap Water		Seawater	
	10WR/90PP	20WR/80PP	10WR/90PP	20WR/80PP
D x 10^{-3} (mm^2/s)	21.17	23.82	23.90	24.33
M_m (%)	55.00	48.35	48.35	50.00

Based on the values obtained from Table 4.4, the 20WR/80PP immersed in the seawater recorded the highest value of diffusion coefficient, followed by the 20WR/80PP immersed in the tap water, 10WR/90PP immersed in seawater and finally 10WR/90PP immersed in tap water. Therefore, the diffusion of water is most favourable in the seawater as opposed to the tap water, whilst it is also higher in the 20WR/80PP compared to the 10WR/90PP. At the initial stage of immersion, the Na+ and Cl- ions present in the sea water accelerate the water uptake through the cracks and voids. Since distilled water is deionised, there are no ions supporting the acceleration of water uptake. Hence, the diffusion coefficient of sample immersed in sea water is higher than that of distilled water [31]. Secondly, the WR particles within the composite are more water absorbent compared to the PP plastic. This is as highlighted in the Figure 4.10 above where the final moisture percentage absorbed by both the 10WR/90PP and

20WR/80PP composites at a minimum of 48.35% also greatly eclipses the moisture absorbed by the pure PP material which recorded a maximum percentage of 4% after 168 hours. Therefore, this shows the higher the concentration of WR in the composite the higher the moisture absorbance of the material. Finally, this causes the diffusion coefficient in 20WR/80PP to be higher than in 10WR/90PP in the sea water and tap water.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The WR/PP plastic composite was produced though a process of first drying and grinding the WR in to a powder. Then, the WR powder was mixed with the PP and extruded to produce the composite. The watermelon rind/PP composite absorbs more than 10 times the amount of moisture in both the seawater and tap water as compared to the pure PP immersed in distilled water. Therefore, the presence of the watermelon rind within the composite makes the material far more water absorbent compared to the PP alone. The increase in percentage of watermelon rind powder from 10% to 20% used correlates to a more exponential increase in the amount of moisture absorbed over a period of 24 hours. Finally, the composite immersed in the seawater absorbs more moisture than the same composite immersed in the tap water after 48 hours.

5.2 Recommendation

The samples should be tested for their physical properties by carrying out the Tensile test in accordance to ASTM D638 followed by the hardness test according to the ASTM D2240. This would provide an insight into the physical characteristics differences of the Watermelon Rind/PP composite as opposed to pure PP. Furthermore, chemical analysis using the XRD (X-ray powder Diffraction) analysis can also be carried out to analyze the Watermelon Rind/PP composite and classify the state of a crystalline substance. An Energy Dispersive X-Ray Spectroscopy (EDS) analysis can also be carried out to determine the elemental composition of the Watermelon Rind/PP composite. Furthermore, a morphological test such as the Scanning Electron Microscope (SEM) analysis should also be carried out to investigate the surface of the Watermelon Rind/PP composite.

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