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Oils and Water Absorption Behavior of Natural Fibers Filled TPU Composites for Biomedical Applications

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ABSTRACT

Natural fibers from fruit skins are surely inexpensive, non- toxic and environmentally friendly, which give unique advantages over the materials. The addition of natural fillers as fillers in the polymer matrix can produce something called as biocomposites. In the other hand, natural fibers are hydrophilic and tend to absorb water, because of their nature which is rich cellulose making it hydrophilic in nature. Besides their nature to water, the ability of natural fibers to absorb oil also interesting to be studied because the degradation of polymer composites filled with natural fibers due to absorb water often precludes their long-term use in biomedical applications. This composite with these properties can be applied as blood bag, in tissue engineering, drug delivery and scaffold, if appropriate. Other than that, the fabrication of this type of biocomposites will reduce the waste of fruits skin. In this paper, natural fibers from several types of fruit skin were used as filler in thermoplastic polyurethane (TPU) composites. The fibers from pineapple skin, coconut shell, coconut husk, corn cob, rambutan, mangoesteen and banana skin with the percentage of 5%, 10%, 15% and 20% were incorporated with TPU through melt mixing technique. Composites with different type of natural fiber will absorb oil and water at different rates, as well as the effect of filler content in this composite. Overall, the absorption of water and oil increased its percentage when the filler content in the composites increases. The composites with fiber from rambutan, pineapple and banana skin absorb more water than others composites at 20% filler content in the TPU. The composites filled with pineapple and rambutan also tend to absorb more engine oil, as well as cooking oil.

Keywords: Thermoplastic Polyurethane, Natural Fibers, Oil Absorption, Water Absorption, Biomedical.

1. INTRODUCTION

Biocomposites can be fabricated by combining natural fibers as filler, such as kenaf, oil palm, pineapple leaf fibers and various grasses with polymer as matrix. Biocomposites can be employed in biomedical applications because in general, natural fibers have no adverse effect to human tissue which is required to be used in biomedical applications [1]. Other than this, previous researchers have studied the composites combining with natural fiber and their application such as drug/gene delivery, tissue engineering, joint and bone fixture [2], drug delivery [3], orthopedics and cosmetic orthopedics [1], antioxidant and anti cancer activities [4]. Malaysia is rich in local and seasonal fruit. Most of these fruits have a thick skin and only the contents were eaten. Fruit skin is necessarily removed and becomes waste. Fruits skin has been processed to obtain fibers, then from scrap, it can be used again [5]. Natural fibers in this study were pineapple, coconut husk, coconut shell, banana skin, corn cob, mangoesteen and rambutan. It has been known that natural fibers from fruits and plants were highly hydrophilic due to

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hydroxyl group in cellulose. This study focused on hydrophobic and oleophilic observation for a various type of natural fibres. All natural fibers that are reviewed will act as fillers in TPU. The ability of fibres to absorb water and oil are reviewed through absorption testing. In addition, water and oil absorption capacity also been studied with the correlation of fiber content as filler in TPU for example in [6], [7]. If the fiber content increased, water absorption is also increasing [8], [9]. The type and structure of the fibers are also a factor of the absorption. The content of cellulose in each type of natural filler also played an important role because the hydroxyl group in cellulose [9]. Some natural fibers are favorable for oil absorption due to their structure, such as hollow fiber. In other hand, the type of oils may give different result, for example the density and viscosity. Vegetable oil is heavier than motor oil and also vegetable oil has lower viscosity, as the result of Dong [10].

Nowadays, many researchers have used natural filler from fruit skin as filler in their study to investigate the mechanical properties of the composite. Besides that, studying the effect of oil and water absorption is also categorized as an important issue. This is because, we need to determine it before finding successful of other application of these composite. The aim of this study is to identify the potential of each type of natural fibers used in TPU composites. Therefore, the composite can be found in biomedical applications. The composites that are able to absorb water and oils actually tend to swell. It should obtain some important common properties in order to be applied in the human body either for use alone or in combination.

2. MATERIAL AND METHODS

Thermoplastic polyurethane (TPU) in pellet form was supplied from Duplas Marketing Sdn. Bhd. The local fruits and its waste were coconut (shell and husk), pineapple (leaf), mangoesteen (rind), banana (skin), corn (cob), rambutan (rind) and durian (skin) were collected from market, stall and village. The dried wastes were dried under the sun and grinded using grinding machine to produce fibers in the small size between the ranges of 50 to 125 μm. The composites were prepared by melt mixing technique using internal mixer. The composition of TPU and natural fibers are 95/5, 90/10, 85/15 and 80/20. The melt mixing were carried out at temperature 180°C with mixing speed of 60 rpm for 10 min. Oil and water absorption test has been done to prove the ability of TPU filled natural fibers either in the nature of hydrophilic, oleophilic or even both. The oil absorption was using engine and cooking oil as the medium and the testing was followed ASTM Oil No. 3 [9]. The water absorption only using distilled water as a medium and refer to ASTM D570 [11]. The samples were weighted for everyday at room temperature and calculated using the equation of;

$$Absorption\ \% = \frac{Intialweight - finalweight}{finalweight} \times 100$$

3. RESULTS AND DISCUSSION

The process of absorption of water and oils is a behavior of swelling. Water and oil molecules enter the void or interface between the fibers and polymer matrix, as well as the pores inside the fibers itself. This absorption process were tested for 4 weeks by calculated the percentage of absorption and the differentiated on each type of fibers and their percentage. The test is not conducted until the absorption reach a equilibrium stage because the testing only focused on the type of fibers and the percentage of the filler in composites as well as the type of medium (i.e. distilled water, engine and cooking oil), so 4 weeks will be enough, besides each type of natural fiber also has different time to reach its equilibrium stage [12].

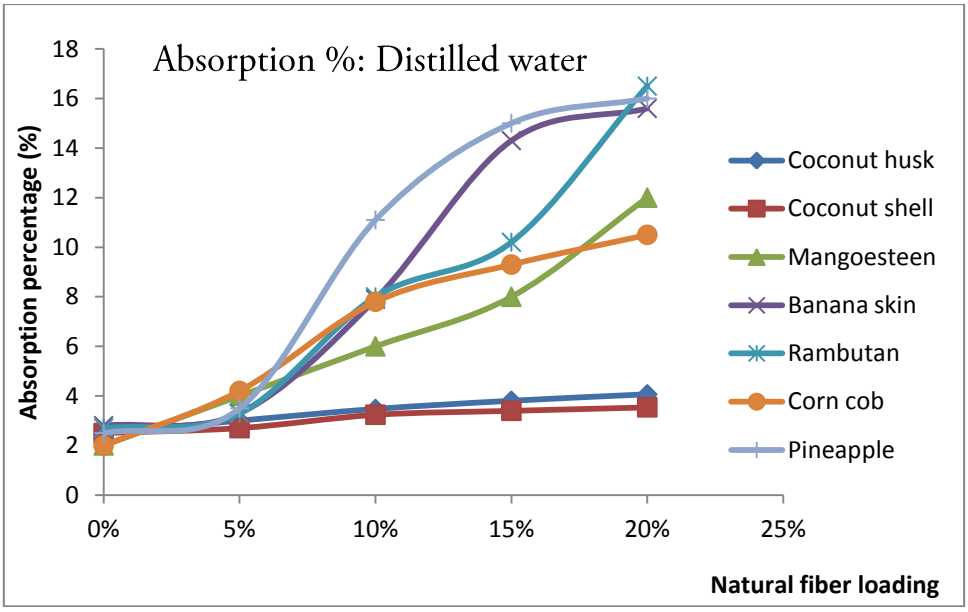

Figure 1. Absorption percentage (medium: distilled water) for different percentage of natural fibers.

In view of this absorption percentage plot, in Figure 1 in distilled water as the increasing of filler percentage, the absorption percentage will also increase. Usually, the same trends were discovered by other researchers [6], [8], [9]. The micro cracks at the interface region were induced by swelling can increase the absorption of water. Water caused the swelling of the fibers too, and it was attributed to the filling up the gaps between the fiber and the TPU. As proven by [9], gaps which formed during compounding process were due to poor impregnation of the filler or the thermal shrinkage.

As mentioned before and already known about the nature of an agricultural and fruits skin fiber, they are highly hydrophilic due to hydroxyl group in cellulose and able to form hydrogen bonds between water and the fillers [13]. By previous research [14], it is well known that filler absorbs water by forming hydrogen bonding between filler and water molecules. However, if comparison was made between the types of fiber, each fiber gives different results and its hydrophilicity. Coconut shells and coconut husks do not show much difference and the water absorption percentage is not much different too, even though the percentage of fiber is increasing from 5wt% to 20wt%. This is due to the structure and nature of these two types of fibers. Coconut shell is more in powder form and irregular shape, oval shape rather than fibrous such as coconut husk, for example in [11].

Comparing the five other types of fibers were found at 20wt% of fibers which is still showed in Figure 1, rambutan, pineapple and banana skin fibers gave highest absorption percentage than mangoesteen and corncob. What can be seen here is the type of fiber itself as the important factor of absorbency [8]. The natures of rambutan, pineapple and banana skin fibers are contain high cellulose content. This is the evident that the absorption process is influenced by cellulose content, as found also in previous research. The authors' [9], [12] stated, natural fibers as filler have been limited by their susceptibility to water absorption, due to their chemical composition which being rich in cellulose, hydrophilic in nature. If we consider the content of cellulose in fruits skin, the Table 1 below can be used as a reference.

Table 1 Cellulose content for seven types of used fruits skin

Fruit skin	Celulose (%w/w)
Pineapple	74-85
Coconut husk	22
Coconut shell	34
Rambutan	81
Mangoesteen	68
Banana	64
Corn cob	42

Taneli [12] also identified three major mechanisms of water absorption which are diffusion, capillary transport and transport of water molecules. The diffusion occurs inside the micro gaps between the chain of polymer which in this study is TPU, while capillary transport happened in the gaps of filler-matrix interface where the impregnation of the fibers and TPU has been incomplete due to compounding process. Then, transport of water molecules was through the micro cracks that can appear in the TPU and this result of the fiber swelling.

It is found that pineapple and banana have high cellulose content and this is the effect of high absorption ability of these composites [9]. The plot in Figure 2 and Figure 3, represent the absorption percentage of engine oil and cooking oil also showed a similar trend to that of distilled water absorption. Almost all the composites show an increasing in percentage of absorption with an increase in the percentage of fibers.

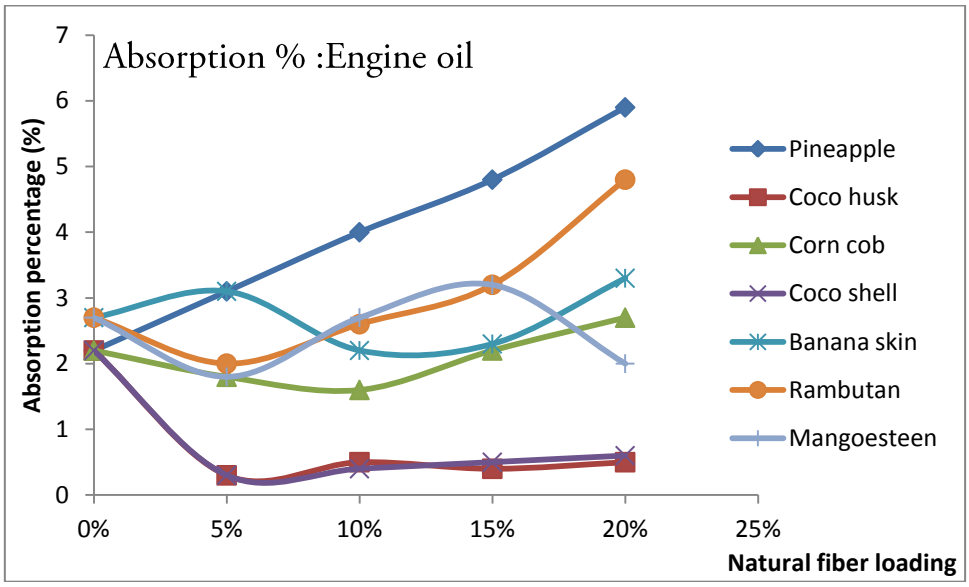

Figure 2. Absorption percentage (medium: engine oil) for different percentage of natural fibers.

Composites with pineapple and rambutan fibers showed the highest absorption of engine and cooking oil compared to others fibers filled composites. Typically, natural organic material from plants and fruits show low oil absorption ability [15]. The comparison between the absorption of distilled water and the engine, cooking oil needs to be seen, considering the absorption percentage of the composites either with pineapple, rambutan and banana skin, is more clearly translated in Table 2.

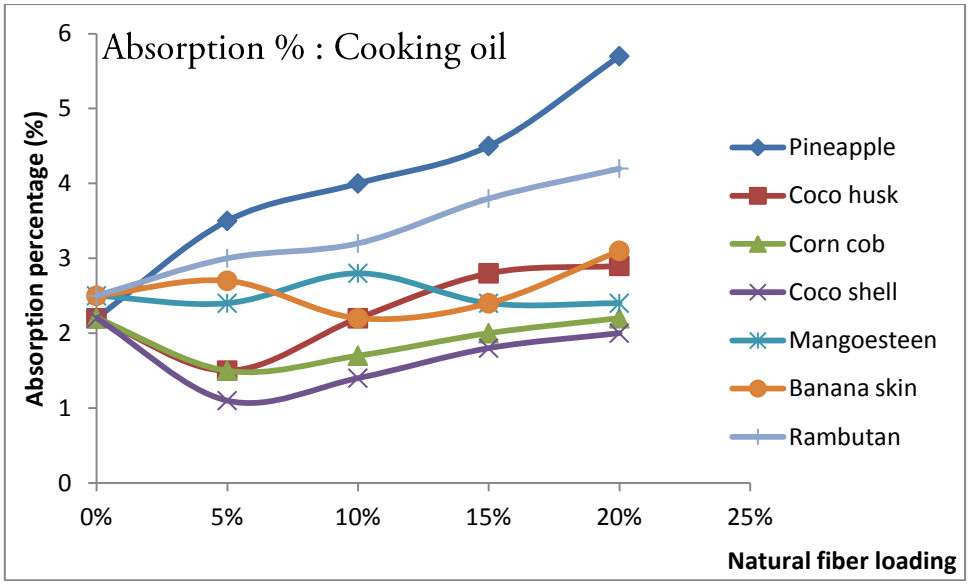

Figure 3. Absorption percentage (medium: cooking oil) for different percentage of natural fibers.

The absorption of distilled water is higher than those of the two types of oil. This proved that natural fibers from fruits skin are hydrophilic and not oleophilic at all. Even on the other hand, due to Marko [16], several types of fibers have some drawback like oil absorption capacity due to its oleophobicity properties. In addition, the density of the water is lighter than oils. Even the density of cooking oil is heavier than engine oil [10] to be firmed that the percentage of engine oil absorption is more than cooking oil. Jorda [7] also supported their findings on vegetable, pump and engine oil and found that absorption capacity was affected by the properties of both absorbent materials and the tested oils.

Table 2 Comparison of absorption for pineapple, rambutan and banana skin

Fibers	Distilled water (%)	Engine oil (%)	Cooking oil (%)
Pineapple	16.0	6.0	5.8
Rambutan	17.0	4.8	4.0
Banana skin	15.8	3.3	3.2

4. CONCLUSION

Biocomposites offer some opportunities for biomedical application with advantages in low cost light weight environmentally friendly and bio-renewable. In other hand, their absorption behavior in water and oil has become disadvantages as well. The main objective of this study was to verify and determine the absorption percentage for the TPU filled five types of fibers composites, against distilled water and engine, cooking oil. Concerning the percentage of fibers as filler, these results show that the absorption percentage was increased with the increasing of filler content from 5% to 20%. Furthermore, the comparison between each type of fibers, pineapple, rambutan and banana skin fibers as filler in TPU composites showed the highest absorption in distilled water and both oils. These due to the high cellulose content of each fiber, beside the structural of the fibers itself. However, by comparing between water and both oils, all composites with different type of fibers absorbed more distilled water than oil, in order that natural fibers are hydrophilic.

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