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The effect of chemical treatments on tensile strength and absorption ability of epoxy/natural fibers composites

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The effect of chemical treatments on tensile strength and absorption ability of epoxy/natural fibers composites

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Abstract. Natural cellulose from agricultural waste, fruit skin, stalks, and so on is considered as recyclable and may have some potential as oil and water absorbent. Besides it is readily available and environmentally friendly it also inexpensive because they are waste, non-toxic and biodegradable. However, the natural fibres are hydrophilic in nature, so it tends to absorb water. Chemical treatments can usually overcome this problem. Usually, acid and alkali treatments are very popular among researchers. In this study, we focused on seeing the differences in natural treatment on acidic and alkaline using citric acid (vinegar) and sodium bicarbonate (soda) of certain three types of selected fibres. The 24 hrs treatments were studied on coconut coir, banana stem fiber and sugarcane bagasse. The tensile strength has been investigated and compared. All fibers were observed highest tensile strength after treated with alkali compared to acid. Treatment with alkali is more suitable for natural fiber in order to clean the fiber surface, thus help to get better fiber-matrix interaction. These are the reason of highest in tensile strength. Overall, the absorption of oil and seawater depends on the type of fibre itself. All treated fibers tend to absorb more seawater and alkaline treated fibers absorbed more cooking oil. Treated coconut coir have tendency to absorb both medium than other fibers. The type of treatments, will give an effect on the fibres' surface, remove the impurities and reduce the hydrophilic properties, so that provide decreasing or increasing of cooking oil and seawater uptake.

1. Introduction

The addition of natural fibers as fillers in the polymer matrix which can solving nowadays environmental and 3R (Recycle-Reuse-Reduce) issues, due to its low cost as well as easy to degrade [1]. The natural fibers are the one of popular resource that uses as reinforcement or filler in polymer matrix [2, 3]. Coconut coir, banana stem fibers and sugarcane bagasse are some of the sources of natural fibers that have potential to use as filler in thermoplastic polymer, which have been studied before [4]. The main problem in the use of natural fibers is its hydrophilic properties that are not compatible with the hydrophobic nature of the matrix material. Due to this major issue, the natural fibers need to treat before use it as filler, to reduce the hydrophilic properties. There are several recent studies that have treated coconut coir with alkaline but seem not effect the mechanical strength of the composites [5], but the chemical treatment resulted in reduce water absorption behavior as proved by Narender [6]. Juliana [7] presented that alkali treatment on sugarcane bagasse produced the best reinforcement for composites due to excellent fiber-resin bonding. This showed that, alkaline treatment is highly proven to improve the properties of the fibers. Many researchers have been studied on banana stem fibers too, which also treated with alkali solution. It appeared to enhanced the interfacial bonding but little advantage over the untreated fibers. Bakri [8] concluded that, better adhesion of fiber-matrix in banana stem fiber/epoxy composites.Limited work reported regarding the acidic treatment so due to that, we aim to evaluate the effect of an eco-friendly and cost effective treatment method based on the use of commercial baking soda (alkali treatment) and vinegar (acid treatment) on these three types of natural fibers. The tensile strength of the epoxy/treated natural fiber has been investigated and compared. Also, we determined the swelling percentage of the composite in cooking oil and sea water to study the level of absorption by the composite and to provide the hydrophilic and oleophiclic behaviour of the untreated and treated fiber.

2. Experimental

The preparation of epoxy composite with natural fibers as filler in this study were done in polymer laboratory and material characteristics laboratory in School of Materials Enginering in Universiti Malaysia Perlis.

2.1. Materials

Epoxy resin and hardener (EPOX-IT 80) was supplied from HH Saintifik Enterprise. All natural fibers (coconut coir, banana stem fiber and sugarcane bagasse) were collected from market, stall and village. They were washed and dried under direct sunlight for days to evaporate all the moisture. The dried fibers was shredded and separated into each fiber, then were cutted to 1.5 cm, manually.

2.2. Fiber treatments and preparation of epoxy/ natural fiber composites

The three types of natural fibers (coconut coir, banana stem fiber and sugarcane bagasse) were immersed in vinegar and soda solution for 24 hours. Before that, the vinegar and soda solution were tested the pH value using pH meter. Vinegar was in pH 2 scale (strong acid) and soda in pH 8 scale (weak alkali). After 24 hours of immersion, the treated fibers were washed with water until the pH value becomes 7, which is neutral. The epoxy composite were prepared by hand mixed. Mixing was carried out at room temperature with specification of mix ratio 1 :1 work time 40 min and cure time 24 hours. The mixture were casting in dumbell shape silicon mold, until hardened for about 24 hours.

2.3. Characterization of TPU/natural fibers composites

Tensile testing is to measure the tensile properties and was done using an Instron Testing Machine. The dumbell shape of the sample were about 50 mm according to ASTM 638. Cooking oil and sea water absorption test were conducted to prove the ability of the epoxy composites to absorb cooking oil and sea water, and to provide the hydrophobic and oleophobic properties. The samples with measurements of 20 mm x 20 mm x 1 mm were used as indicted by ASTM D570-98. The test have been observed and determined for 3 days at room temperature. The samples were weighted for everyday and calculated using the following equation;

$$\text{Oil absorption } (\%) = \frac{\text{intial weight} - \text{final weight}}{\text{final weight}} \times 100\% \quad (1)$$

3. Results

The results which were presented here are on the tensile strength, cooking oil and sea water absorption percentage of the composites that have been studied.

3.1. Tensile strength

The tensile strength of the epoxy composites filled three types of different natural fibers are inferred in Figure 1 for both treatments which are (a) soda (alkali) treatment and (b) vinegar (acid) treatment. The neat composite was used as control unit with tensile measured value of 15 MPa. This figure illustrated the evolution of the tensile strength and marked highest was observed at coconut coir and sugarcane, after alkali treatment and also highest at coconut coir treated with acid. Due to various type of fiber, it can be seen that the tensile strength is affected by filler type and their surface area [9]. By comparing between both treatments for each natural fiber; coconut coir for example, it showed the tensile strength of the epoxy composites are higher for alkaline treated than acid treated. Alkali treatments significantly efective to clean the fiber surface more than acid treatment. This may explained why most of researcher tend to choose alkaline treatment instead of acidic treatment. Alkaline treatment will give a better and more desirable result. The cleanliness and roughness in the fiber surface due to fiber delignification process was observed to increase by different type of treatment between acid and alkali [10] and the effect to different type of fiber as well.

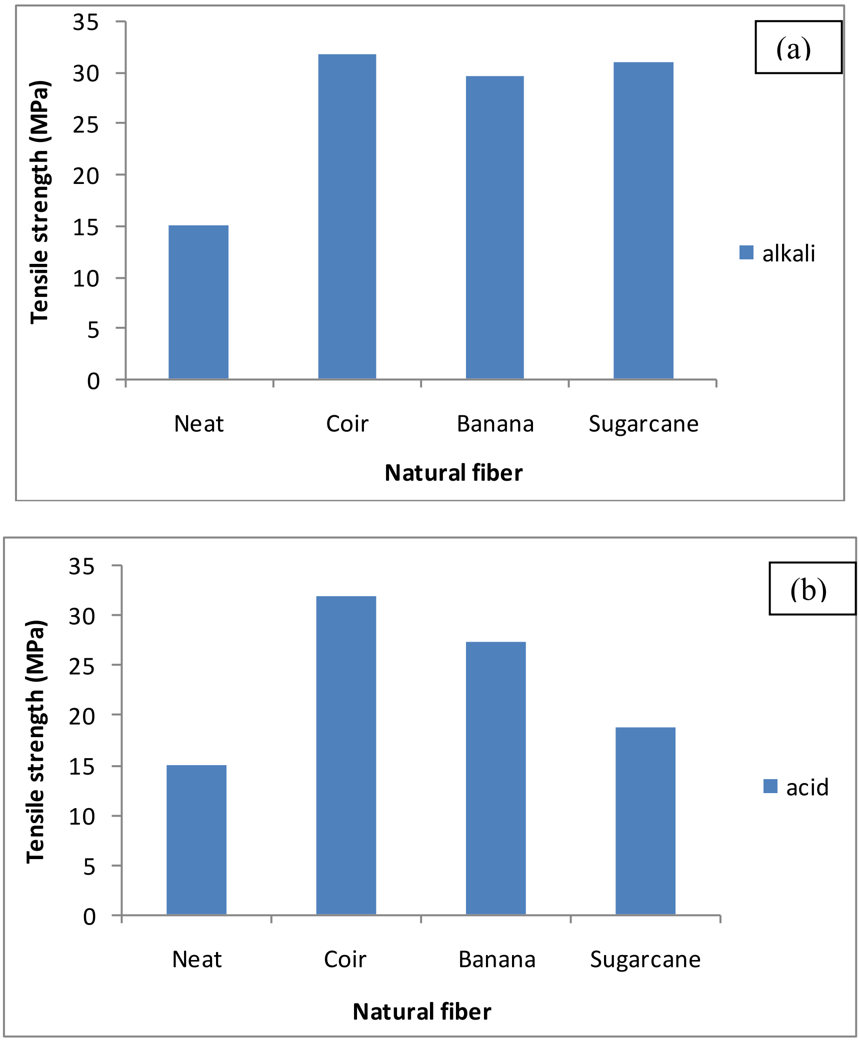


Figure 1. Tensile strength of the variation epoxy/natural fibers composites (a) alkaline treated (b) acidic treated.

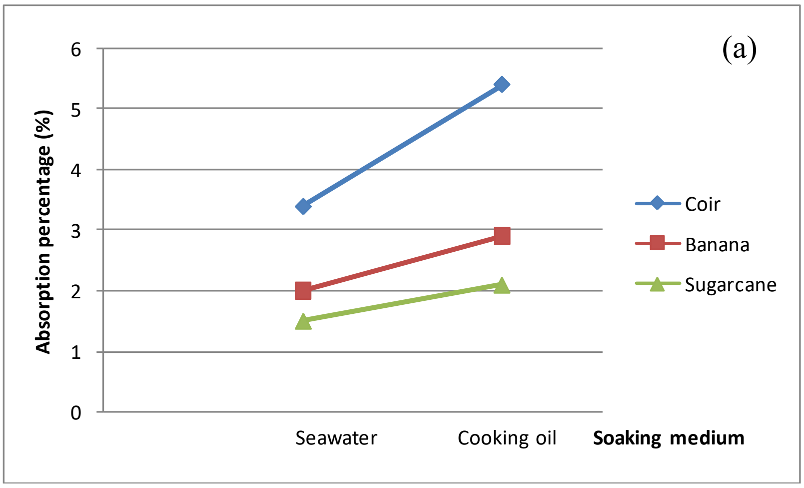
Most of the properties showed higher tensile strength reading for treated fiber and its composites rather than untreated. This is attributed to the fibers tending to get better fiber-matrix interaction after treatment [11]. Untreated fibers have low tensile strength because they are hydrophilic and incompatible with matrix [12]. Most of researchers conclude of improvements in tensile strength after treatments and proved by morphological examination. The treatment will improve adhesion between the hydrophilic fibers and hydrophobic epoxy [13]. The weak filler-matrix adhesion was due to low compatibility between both and thus lead to poor strength properties of the epoxy composites filled with untreated natural fibers.

Treatment also showed an increase in the surface roughness and quality in terms of reduction of impurities [14]. Most of findings found the same reason and Venkata [11] proved the same. They stated that, the roughening the surface of the fiber is due to removal of non-cellulose with acid treatment. The removal of certain portions of hemicellulose, lignin, waxy substances and natural oils covering the surface of the fiber surface is also important proof that support the finding [13, 14].

Besides, as we know, every natural fiber has its own surface morphology which decided the interfacial fiber-matrix adhesion and these will affected the mechanical/ physical properties [15]. This explained why different type of natural fiber will gave different highest to lowest tensile strength value, even have been treated with same medium, soaking time and concentration. Furthermore, the untreated fiber which filled in others matrix also will give same trend, as revealed in our previous research [16]

3.2. Cooking oil and seawater absorption behavior

The pattern of oil absorption after 3 days by the epoxy composite with different types of natural fibers are shown in Figure 2 (a) & (b).



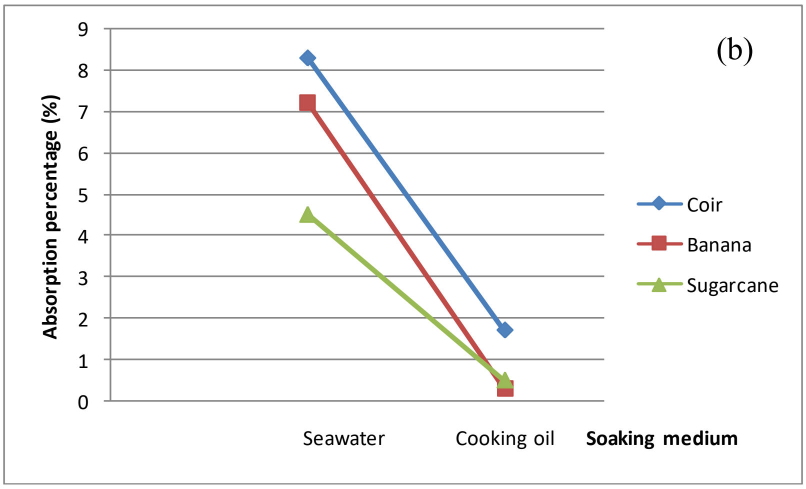


Figure 2. Swelling percentage for epoxy/natural fiber composites in cooking oil and seawater after 3 days (a) alkaline treated (b) acid treated.

All alkaline treated fibers showed higher cooking oil absorption percentage and acid treated fibers showed highest tendency to absorb seawater. Cooking oil has low viscosity than seawater [4] so that the oil molecules can move easily to the pores of the fiber assembly and hence higher absorption capacity was observed. If we compare both types of treatment, clearly to prove that alkaline treated fiber absorb less cooking oil and seawater. The treatments change the fiber surface chemistry and clean the fiber which results in reducing water absorption tendency [17] and alkali treatment is very effective in helping towards this objective until the absorption of the medium can be cut off.

We may see that, coconut coir fiber exhibited the highest oil absorption capacity in both medium and treatment method. Due to Marko [18], several types of fibers have some drawback like oil absorption capacity due to its oleophobicity properties. Other reason is due to their shape, surface area and their nature. By looking to the shape and nature of filler, we can say that coconut coir contain long and fine fibrous structure which can provide easy access to the cooking oil [19] and sewater molecules.

Strong fiber and matrix interfacial adhesion also can help to diminish the medium penetration and avoiding the worsening of the mechanical performance of the composite, which we may relate to the tensile strength in previous discussion. Long fiber with hollow tubes structures may serves a valuable for oil absorption. Jayamol [20] stated that, if the surface area is large, then there will be more area for absorption of cooking oil and seawater molecules. Surface cavities are filled with oil molecules that have been absorbed.

4. Conclusion

It is well known that, the hydrophilic surface of natural fibers shows poor compatibility with hydrophobic matrices like epoxy resin. Chemical treatment may improve its surface, enhanced the filler-matrix adhesion thus lead to high mechanical properties and lower water absorption. Two types of chemical treatments have been compared between alkali treatment of baking soda and acid treatment of vinegar. All fibers were observed highest tensile strength after treated with alkali compared to acid, and they tend to absorb more seawater than cooking oil. Alkaline treated fibers absorbed more cooking oil compared with acidic treatment. Among three types of natural fibers, coconut coir showed the best fiber for treated with alkali to give highest tensile strength and hydrophobic properties. Alkali treatment improves the fiber-epoxy interaction and gives an effect on the fibres' surface, remove the impurities and reduce the hydrophilic properties.

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