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Effect of Chemical Treatment on Water Absorption Capability of Polyester Composite Reinforced with Particulate Agro-Fibres

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Abstract

This study determined effects of chemical treatment on the degradation of polyester composite reinforced with agro-fibres. The fibres, after being chemically treated with 1M of hydrogen peroxide, sodium hydroxide and potassium hydroxide solution, were sun-dried and pulverized. Screened particulate fibres obtained from 800 µm sieve were mixed with polyester resin in predetermined proportions. Water absorption test was carried out on the samples and it was observed that the treated fibres showed lower water absorption rates (degradation) as compared with the untreated fibres. The overall responses confirmed the chemical treatment adopted as suitable for pre-treatment of agro-fibres to forestall degradation.

Keywords: Agro-Fibres, Chemical Treatment, Degradation, Water Absorption, Particulate, Polyester Composites

1. Heading

One of the most important issues in natural fibres polymeric composites is the degradation behaviour of the composites when exposed to environmental conditions such as humidity, sunlight or microorganisms. The poor resistance of the fibres to water absorption can have undesirable effects on the mechanical properties and the dimensional stability of the composites. It was reported that water uptake leads to the degradation of the fibres and the fibre–matrix interface resulting in a loss of mechanical performance [3]. The properties of natural fibres are affected by many factors such as variety, climate, harvest, maturity, retting degree, decortications, disintegration (mechanical, steam explosion treatment), fibre modification, textile and technical processes (spinning and carding) [9].

The most serious problem connected with natural fibres is its hydrophilic nature, which causes the fibre to swell and ultimately rot through fungi attack. Natural fibres are hydrophilic as they are derived from lignocellulose, which contain strongly polarized hydroxyl groups. These fibres, therefore, are inherently incompatible with hydrophobic thermoplastics, such as polyolefins. Moreover, difficulty in mixing because of poor wetting of the fibre with the matrix is another problem that leads to composites with weak interface [2]. However, it was reported that even though the hydrophilic character of natural fibres would lead to composites with weak interface but pre-treatment of natural fibres would aim at improving the adhesion between fibres and matrix [10].

A possible solution to improve the fibre polymer interaction is by using competibilizers and adhesion promoters which reduce the moisture absorption. Surface treatments of the fibre with saline make the fibre more hydrophobic [8]. Hydrothermal treatment is one of the approaches to reduce moisture absorption of natural fibres, which can increase the crystallinity of cellulose and therefore, contributes to a reduced moisture uptake. Moreover, in hydrothermal treatment, a part of hemi-cellulose is extracted thereby decreasing the moisture absorbance [6]. Duralin process can be used to improve the quality of natural fibres. It has got a number of advantages such as no dew retting required, increased fibre yield, improved fibre quality consistency, reduced swelling and resistance from moisture, increased thermal stability, improved resistance to fungus and better mechanical properties [4,5].

In order to develop composites with excellent mechanical properties, it is necessary to solve the problems by applying suitable treatments to enhance the compatibility between fibres and the matrices [1]. Hence, this study adopts chemical treatment method to tackle this degradation problem.

1.1 Materials and Experimental Setup

1.1.1 Materials and Fibre Preparation

The materials used include yam stem and coconut fibres, polyester resin, cobalt 2% in solution (cobalt nasphthenate), methyl ethyl ketone peroxide (accelerator), poly vinyl acetone, ethanol, hydrogen peroxide, sodium hydroxide, potassium hydroxide and teflon sheet material. Fibres were obtained from the brown husk of a ripe coconut plan and stems of harvested yams. The fibres were washed using distilled water and sun-dried. These were then grinded to remove scales and internodes from the yam fibre and to further shred the coconut husk. The fibre mass was pulverized in a ball mill and sieved through 800 µm mesh.

1.1.2 Fibre Treatment

Part of the fibres (yam and coconut) was chemically treated in 1 M hydrogen peroxide, sodium hydroxide and potassium hydroxide solution in water while some were left as control samples. 120 g of each of the chopped fibre was chemically treated at 70 ^{0}C for two hours in a water shaker bath. After the appropriate soak time, the fibres were rinsed in distilled water until the pH of the rinse solution stabilized at 7 so as to remove the excess of the chemicals sticking to the fibres. The fibres were later oven dried before pulverizing. 10 g of each of the treated and control fibres were tested for lignin, cellulose and hemi-cellulose so as to ascertain the efficiency of each of the treatment given to the fibres in removing lignin, hemi-cellulose and detainment of cellulose which is the fibre needed for the reinforcement.

1.1.3 Process Description

The materials, polyester resin, fibre, catalyst and accelerator were weighed to conform to the mould formulation. Teflon sheet was cleaned and its surface was coated with Poly Vinyl Acetone to serve as mould release agent to ensure the formation of a pure resin on the outer surface of the moulding. 40 g of polyester resin was poured into a glass beaker. 0.5 mole of accelerator and 0.5 mole of catalyst were added and stirred. The pulverized fibre was added and stirred for some minutes before curing at room temperature. After curing, it was ejected from the mould and trimmed to desired sizes. Several samples of varying fibre volume of 0.5, 1.0, 1.5 and 2.0 g were repeated for each of the treated and control portions of the fibres.

2.0 Experimental Results and Discussion

The results obtained are presented in Figures 1—5.

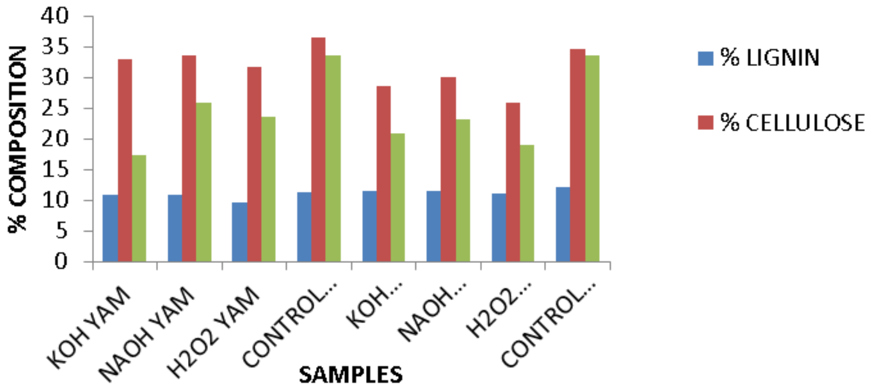

Figure 1: Plot of % Composition against Samples of Fibre Constituent (Lignin, Cellulose and Hemi-cellulose)

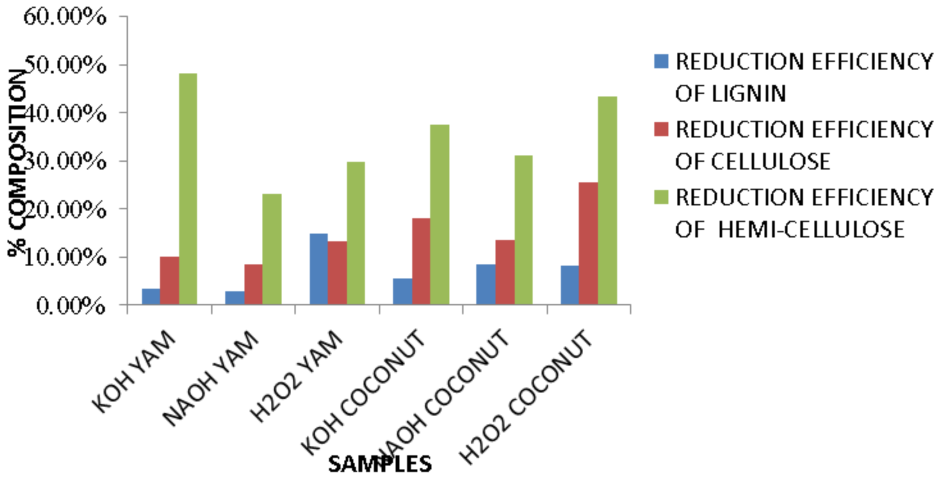

Figure 2: Plot of % Composition against Samples for Reduction Efficiency values of Lignin, Cellulose and Hemi-cellulose.

2.1 Fibre Constituents Test

Figures 1 and 2 revealed the fibre constituents value and the reduction efficiency of the different treatments respectively. From Figure 1, it was shown that untreated samples have the greatest quantity of lignin and hemi-cellulose as compared to the treated fibres.

From Figure 1, it was observed that KOH treatment gives the best chemical treatment for yam fibre because the cellulose content was retained to a considerable value of 32.86 while the lignin and hemicelluloses have a reduced retention value of 10.83 and 17.36 respectively as compared with the cellulose content. Since the essence of the treatment is to reduce the lignin and hemicelluloses while the cellulose which is the required fibre must be retained. However for coconut fibre, NaOH treatment gives the best chemical treatment as the cellulosic content retained is 29.96 while the lignin and hemicelluloses retained are 11.58 and 23.09 respectively.

Figure 2 showed that coconut fibre treated with H_2O_2 has the highest reduction efficiency value of cellulose as compared with other chemical treatments. The cellulosic constituent was highly reduced with a reduction efficiency value of 25.42 % which is not desirable. The H_2O_2 treated yam fibre has the highest reduction efficiency for lignin with a value of 14.8 % as compared with other chemical treatments. However, this does not make it the best because the reduction efficiency value of the cellulosic content is high as compared with KOH treated yam fibre and NaOH treated coconut fibre. KOH treated yam fibre however has the highest reduction efficiency value of 48.29 % for hemicelluloses as compared with all other chemical treatments and a slightly higher reduction efficiency value of 3.39 % for lignin with a cellulosic value of 10.14 % as compared with NaOH yam fibre treatment which are 2.85 % and 8.45 % for both lignin and cellulose respectively. The lignin, hemicelluloses content of coconut fibre is higher than that of the yam fibre. It was reported that coconut fibre taken from coconut fruit has high rigidity and hardness which indicates its high content of lignin [3]. Therefore, KOH treatment gives the best chemical treatment for yam fibre.

For coconut fibre, NaOH treatment gives the best chemical treatment because it has the lowest reduction efficiency value of 13.66 % for cellulose as compared with the other chemical treatments for coconut fibre.

2.2 Water Absorption Test

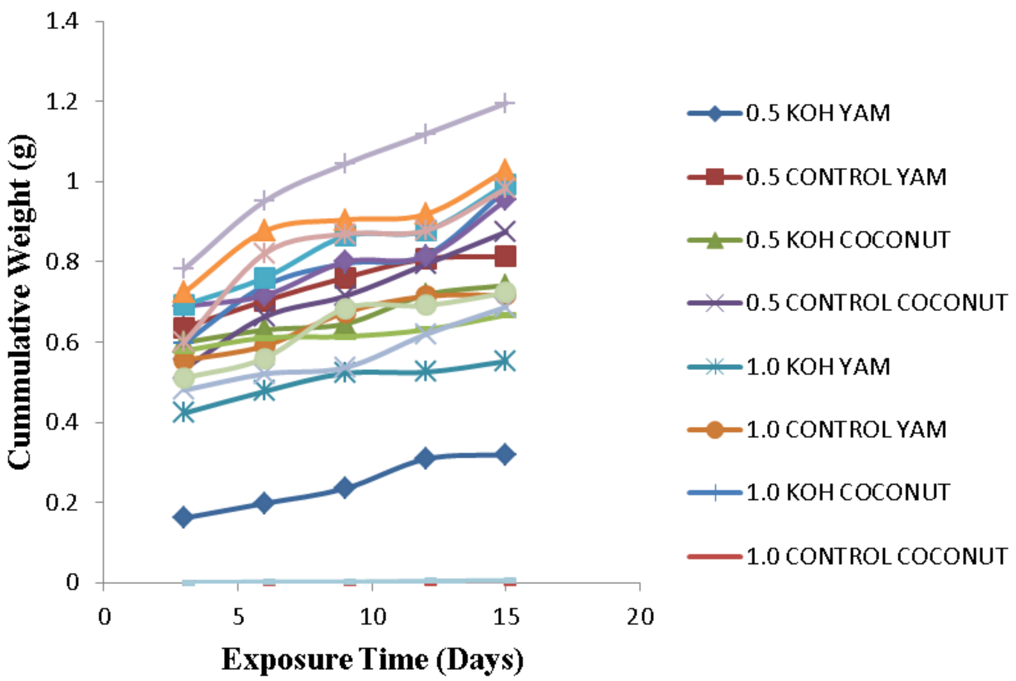

Figure 3: Plot of Commulative Weight (g) against Exposure time for Water Absorption Test Carried out on Composite Materials Reinforced with both Coconut and Yam Fibres Treated with KOH and Control Samples

Figure 3 above shows the Plot of Cummulative Weight (g) against Exposure time for Water Absorption Test Carried out on Composite Material Reinforced with both coconut and yam Fibres Treated with KOH and control samples. Yam fibre treated at 0.5 g fibre weight fraction has the least water absorption. Untreated coconut fibres at 2.0 g fibre weight fraction have the highest water intake. The high water uptake of coconut fibre as compared with the yam fibre is due to the high content of hydrophilic nature of coconut fibre. This corroborates the report of Karlsson [3] that the water uptake was due to the hydrophilic character of natural fibres which is responsible for the water absorption in the composites, and therefore a higher content on fibres leads to a higher amount of water absorbed.

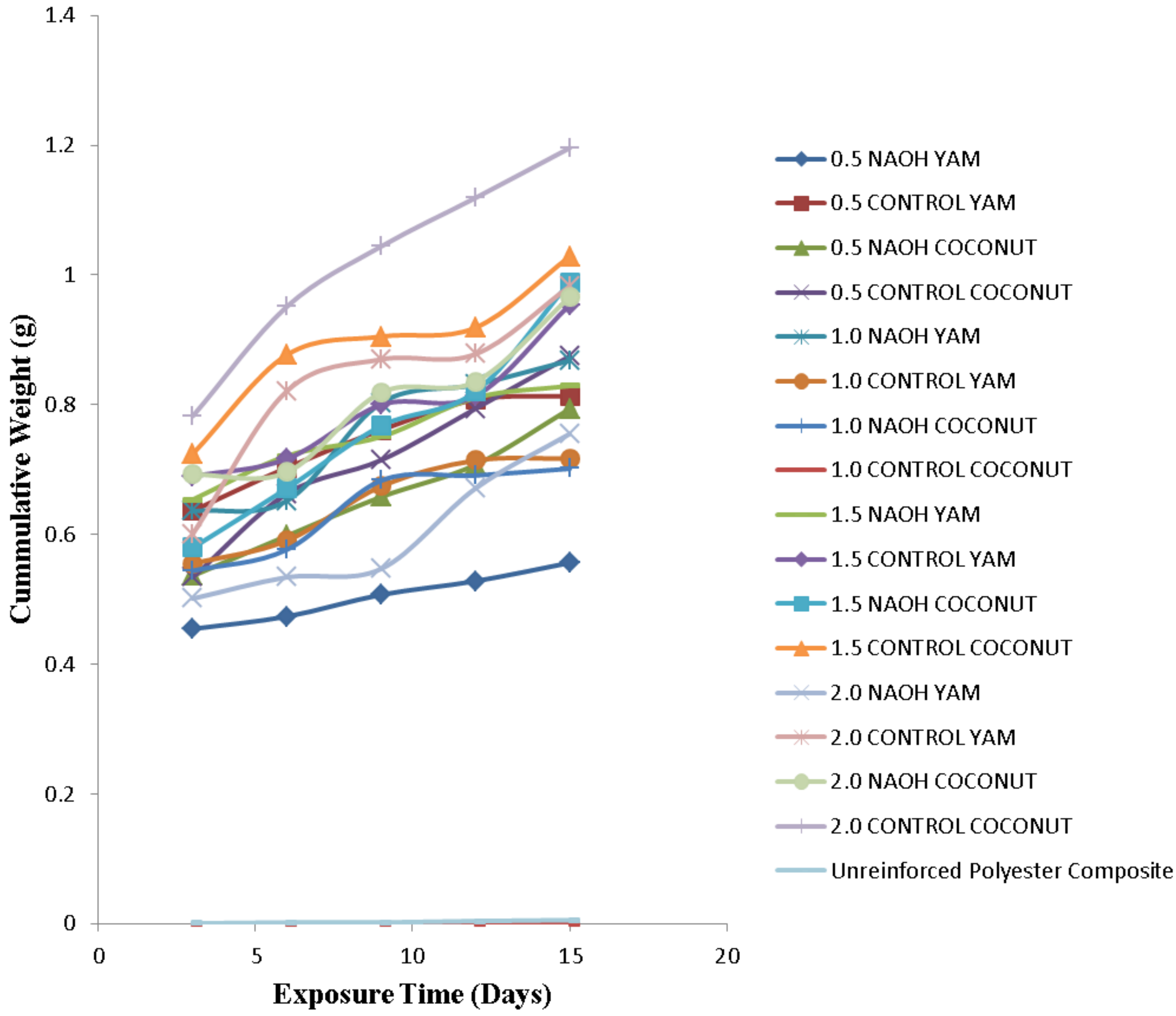

Figure 4: Plot of Commulative Weight (g) against Exposure time for Water Absorption Test Carried out on Composite Material Reinforced with both Coconut and Yam Fibres Treated with NaOH and Control Samples.

This plot shows that yam fibre treated at 0.5 g fibre weight fraction has the least water absorption while untreated coconut fibre at 2.0 g fibre weight fraction has the highest water intake.

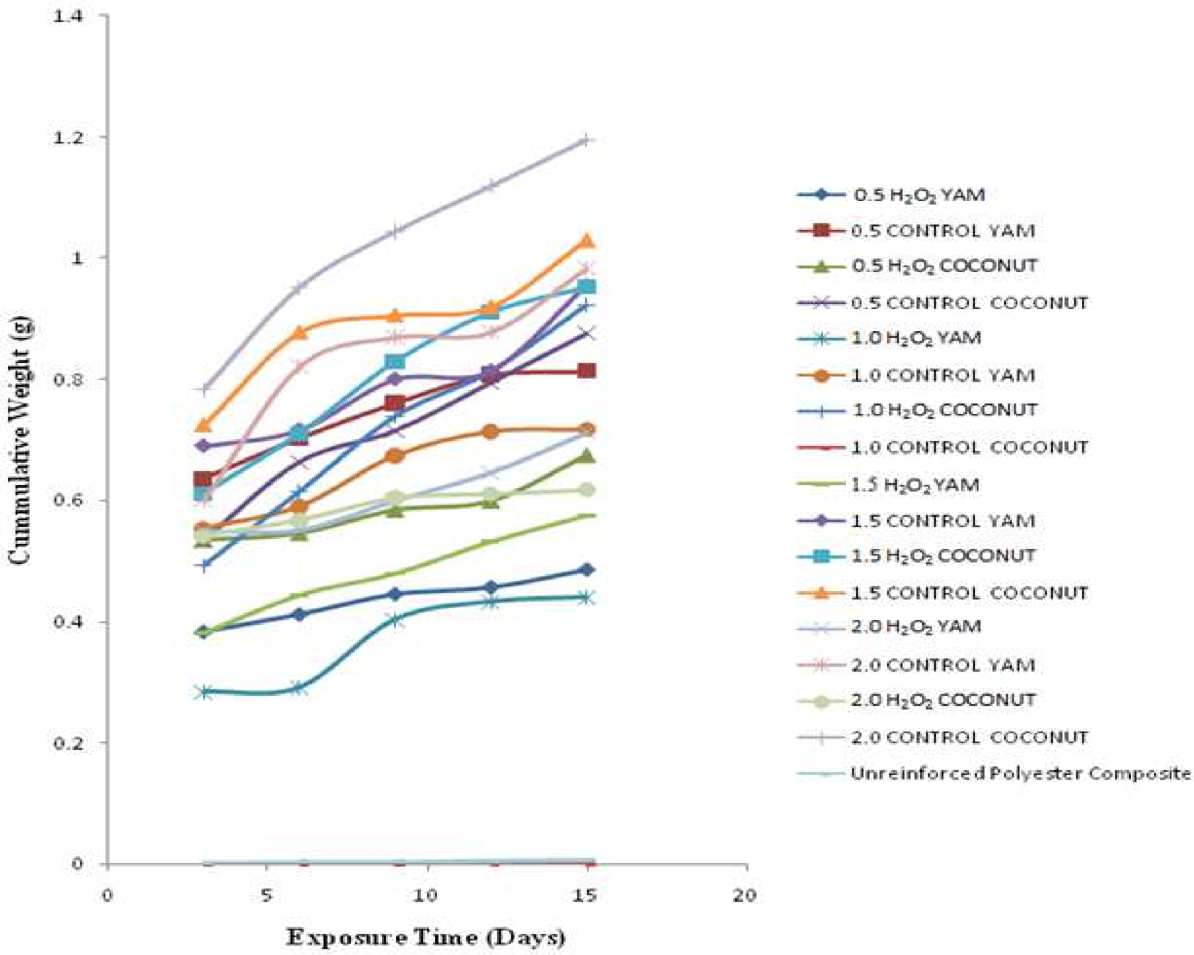

Figure 5: Plot of Commulative Weight (g) against Exposure time for Water Absorption Test Carried out on Composite Material Reinforced with both coconut and yam Fibres Treated with H_2O_2 and control samples.

This plot shows that the treated yam fibre at 1.0 g fibre weight fraction has the least water absorption followed while untreated coconut fibre at 2.0 g fibre weight fraction has the highest water intake.

Figures 3 to 5 point to the fact that the treated and the untreated yam fibre show the least water absorption as compared with the treated and untreated coconut fibre which shows higher water absorption rate.

The rate at which the composites absorb water is very low as shown in their cumulative weight within the fifteen days. Also, the rate at which the composites absorb water increases with increasing exposure time. Coconut fibre is more hydrophilic in nature than the yam fibre as this was shown in Table 4.0 that its percentage of lignin is higher than that of the yam fibre making it to have higher affinity for water absorption than the yam fibre. The unreinforced sample however shows no significant changes in their water absorption this is due to their hydrophobic nature [7]. The water absorption test shows that the chemical treatment given to the fibres is effective as all the treated fibres show the least water absorption values compared to the untreated.

3.0 Conclusions

The study described above shows that the chemicals selected for the treatment of selected agro-fibres were suitable to minimise water absorption rate in composite materials and thereby making the selected agro-fibres to be suitable for reinforcement in polyester composite and can be used for the production of composite with improved performance. However, the following conclusions were drawn from the research work:

i. The rate at which each fibre absorbs water increases with increasing number of exposure or immersion days with minimum and maximum values of 0.0027g and 0.7823g respectively.

ii. The rate at which the composite samples absorb water is generally low.

iii. Treated yam fibre at 0.5 g fibre weight fraction has the least water absorption cummulative value as compared with coconut fibre.

iv. KOH gives the best chemical treatment for yam fibre with 32.86 % cellulose, 10.83 % lignin and 17.36 % hemi-cellulose while NaOH gives the best chemical treatment for coconut fibre with 29.96 % cellulose, 11.58 % lignin and 23.09 % hemi-cellulose.

v. The chemical treatments given to the agro-fibres prevent degradation of the fibres due to water absorption.

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