Water Absorption Capacity of Date Palm (*Phoenix dactylifera*) Pits Reinforced Epoxy Composites

Kolawole, S. A[1]., Abdullahi, D[2]., Dauda, B.M[3]., Ishiaku, U.S[4]

[1]Department of Chemistry, University of Abuja, Gwagwalada- Abuja.

[2, 3,4]Department of Textile Science and Polymer Technology, Ahmadu Bello University, Zaria.

Abstract: ***The hydration behaviour of composites upon exposure to environmental conditions is an important issue. This could offer important information on the mechanical properties of such composite when used for outdoor applications. Immersion of composite in water for period of time is an effective way to investigate the moisture absorption behaviour of such composites. Date pits particles (150μm) of filler loading 10, 20, 30, 40 & 50 wt% composites were prepared. Composites sheets were prepared via hand lay-up technique in a fabricated glass mould. The hydration capacity was determined by measuring water uptake of specimen at regular interval of 24hrs. Absorption tests were performed at room temperature of 25^{o}C for 768hrs. The results showed that water absorption increases with the increase in wt% of the filler loading. In this paper, the absorption behaviour of date pits filler reinforced epoxy composites showed that the addition of 10% filler weight into the matrix increased the water absorption of the composite by 0.33% after 24hrs of immersion while increasing the filler content by 50% weight increased the percentage absorption to 1.12. The highest value of 9.312% was recorded for composite of 50% filler ratio after 768hrs.The water absorption of date pits reinforced epoxy composites was found to follow a Fickian behaviour where it did reach equilibrium.***

Keywords: Date pits; Composite; Fickian behaviour; Water absorption; Diffusivity; Epoxy.

1. Introduction

Natural fibre as substitute to synthetic/glass fibre in reinforced materials has been found to offer many environmental advantages, such as improved toughness, stiffness and strength of plastic. Apart from being biodegradable, they have low density and produce environmentally friendly polymeric composites [1,2].

Palm date fruits consist of three main parts: date flesh, date pit (seed), and skin. The pit is a major by-product of the date palm processing industry and is mainly used as animal feed. Hamada *et al* (2002) reported that date pits from three different varieties contained 7.1– 10.3% moisture, 5.0–6.3% protein; 9.9–13.5% fat; 65– 69% neutral detergent fibre; and 1.0–1.8% ash. Accordingly, total carbohydrate content of date pits ranged from 71.9 to 73.4% for the three varieties of date palm trees. These pits contained a large quantity of fibre which can be utilized in the production of polymer composite [3]. Therefore, producing composites from this agro-waste and characterisation of the composite will offer more knowledge to natural filler composite production.

Epoxies are important thermosets which are greatly used as materials for fibre-reinforced composite materials and structural adhesives [4,5]. The role of matrix is to keep the fibres in a desired location, orientation and to effectively transfer the stress to fibres. Epoxies are mostly used in natural fibre reinforced polymer composites due to high tensile strength, low shrink rate, low flow rate, low volatility during cure, etc. [6]. Consequently, by combining thermosets such as epoxy with natural agricultural waste such as date pits, it is hoped to develop highly beneficial composites that can be used for several structural purposes and as commodity plastics with a better mechanical properties. This could lead to several benefits such low cost, highly renewable and above all changing our world by converting our agro waste to wealth.

The main disadvantages of natural fibres in composites are lower allowable processing temperatures, incompatibility between hydrophilic natural fibres and hydrophobic polymers and moisture absorption of the fibres and in turn the manufactured composite [7].

Although, water absorption could lead to a decrease in the end-user applications of these composites, there is reason to believe that by understanding the limitations and benefits of these composites, date palm pits is not likely to be ignored by the plastic industry for use in formulating plastic products.

The effect of water absorption is important in case the material that has been developed when used for applications comes in contact with water. There is much more information on interaction of water with structural resins. This scientific interest has arisen because water interactions with epoxy resins can degrade the mechanical properties of the resins.

Water can cause the resins to swell and to produce what is called “crazing” of the surfaces. Water absorbed in the resins can reduce the glass transition temperature (Tg) of the polymers and make them weaker.

This study therefore focused on the water absorption capacity of date palm pits reinforced epoxy composite.

2. Materials and Methods

The date palm fruits (source of the pits) used in this study were obtained from Gwagwalada market in Gwagwalada area council, F.C.T; Nigeria. The pits were cleaned to remove contaminants, sundried and thereafter grounded to obtain filler powder using hammer mill machine. The fillers were then made to pass through wire mesh screen to obtain particle size of about 150µm. The fillers were oven dried for 4hrs at temperature of about 70°C before used so as to reduce the moisture content.

The matrixes epoxy (commercially available as epoxy resin (3554A)) with density 1.17g/cm^3 and polyamine curing agent (hardener) with density 1.03g/cm^3 were procured from a local supplier in Lagos, Lagos State, Nigeria and were used as received.

Preparation of Composite Samples

Five levels of filler loading composites (10, 20, 30, 40, & 50 wt%) each were made from fillers (date palm pits) and the matrix(epoxy resin). Virgin resins without filler were equally prepared to serve as control.

This was achieved by mixing the various ratios of the prepared fillers with the epoxy to form homogenous blends. The mixing was achieved via manual stirring method for 10 minutes. The volume ratio of resin to hardener was 100:50, and after being thoroughly mixed with the filler, the resin was poured onto the cavity of glass mould previously covered with aluminium foil so as to serve as releasing agent. The mixture was allowed to cure at room temperature for 24hours before removal as sheet from the mould. The specimens were machined into 40mm by 20mm with 5mm thickness. Three specimens for each composite were tested.

Water Absorption Test (ASTM D570)

Water absorption test was carried out according to ASTM standard. The specimens were dried in an oven for 4hrs at 70°C temperature and then placed in desiccators to cool. Immediately, upon cooling the specimens were weighed. The materials were then immersed in water at room temperature of 25°C for 24 hours. To determine the wet weight, specimens were removed from water, patted dry with a lint free cloth, and weighed immediately in an analytical weighing balance. The absorption capacity of the composites was then monitored for period of 32 days.

Data:

The following calculations were made from results:

i. **Percent Water Absorption:** expressed as percentage increase in weight.

$$\text{Percent Water Absorption} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Dry weight}} * 100$$

ii. **Rate of absorption / Sorption behaviour**: expressed as rate of water absorption per hour.

$$\text{Rate of absorption} = \frac{\%\ \text{change in Water Absorption}}{\text{change in time(hour)}}$$

3. Results and Discussion

Water absorption is used to determine the amount of water absorbed under specified conditions. Factors affecting water absorption include: type of matrix, type of filler used, filler content, temperature and length of exposure. The data obtained sheds light on the performance of the materials in water or humid environments. In this research, the water absorption capacity and the rate of absorption were determined and the results were summarized using figure 1 and figure 2 respectively.

Table 1: Result showing water absorption capacity of date pits/ epoxy composites

		% Hydration of different filler content					
Days	Time(hr)$^{0.5}$	EP	10%	20%	30%	40%	50%
1	0	0	0	0	0	0	0
2	4.899	0.789	1.127	1.158	1.444	1.579	1.91
3	6.928	0.854	1.31	1.521	1.89	2.068	2.662
4	8.485	0.893	1.536	1.777	2.218	2.459	3.101
5	9.798	0.984	1.775	2.059	2.594	2.892	3.649
6	10.955	1.062	1.916	2.194	2.819	3.157	4.009
7	12	1.113	2.017	2.504	3.101	3.457	4.425
8	12.962	1.152	2.184	2.786	3.339	3.674	4.713
9	13.856	1.198	2.381	3.029	3.664	4.093	5.152
10	14.697	1.247	2.579	3.042	3.87	4.345	5.512
11	15.492	1.272	2.565	3.459	4.029	4.359	5.731
12	16.248	1.282	2.624	3.54	4.339	4.834	6.358
13	16.971	1.295	2.681	3.634	4.405	4.946	6.358
14	17.664	1.307	2.755	3.722	4.606	5.211	6.734
15	18.33	1.309	2.818	3.756	4.64	5.253	6.734
16	18.974	1.311	2.931	3.904	4.935	5.483	7.423
17	19.596	1.321	2.987	4.011	4.973	5.658	7.235
18	20.199	1.346	3.029	4.079	5.043	5.798	7.266
19	20.785	1.385	3.044	4.092	5.176	5.91	7.657
20	21.354	1.398	3.156	4.111	5.288	5.993	7.892
21	21.909	1.449	3.17	4.351	5.389	6.035	7.999
22	22.45	1.476	3.269	4.415	5.487	6.121	8.143
23	22.978	1.489	3.311	4.442	5.588	6.311	8.289
24	23.495	1.502	3.382	4.48	5.702	6.522	8.423
25	24	1.508	3.551	4.496	5.866	6.79	8.628
26	24.495	1.601	3.608	4.511	5.933	6.842	8.772
27	24.98	1.605	3.648	4.563	5.997	6.955	8.822
28	25.456	1.605	3.7	4.609	6.056	7.001	8.913
29	25.923	1.605	3.733	4.617	6.159	7.233	9.054
30	26.382	1.605	3.802	4.666	6.303	7.471	9.273
31	26.833	1.605	3.814	4.703	6.419	7.558	9.311
32	27.713	1.605	3.815	4.712	6.476	7.56	9.312

Table 2: Result showing diffusivity of date pits/epoxy composite

Filler content (%)	Diffusivity (mm^2/hr)
0	0.0418
10	0.0157
20	0.0094
30	0.0084
40	0.0062
50	0.0062

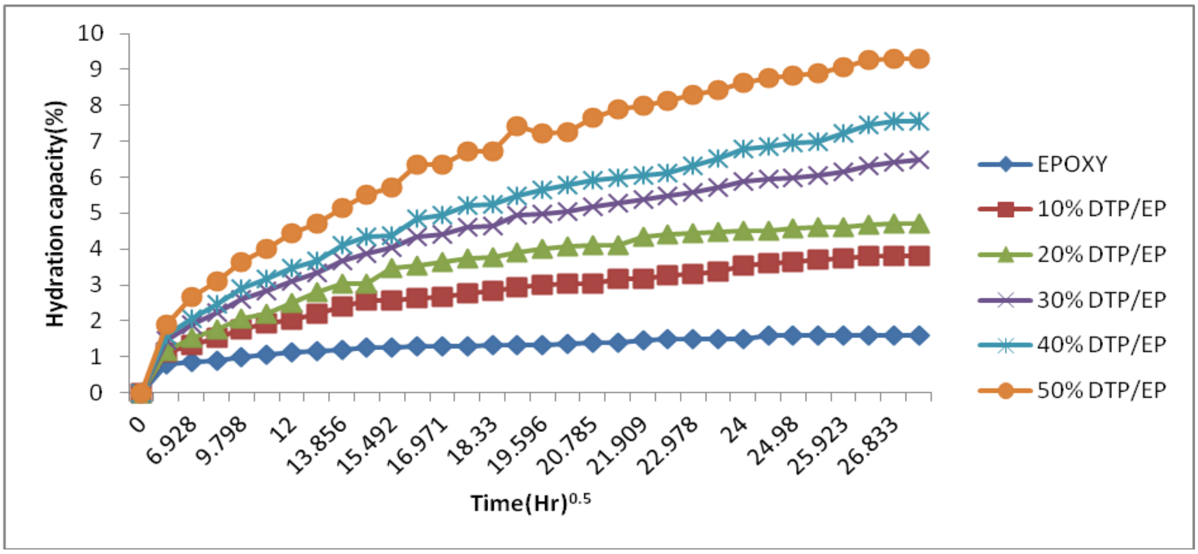

Figure 1: Water absorption curves of date pits/ epoxy (DTP /EP) composite.

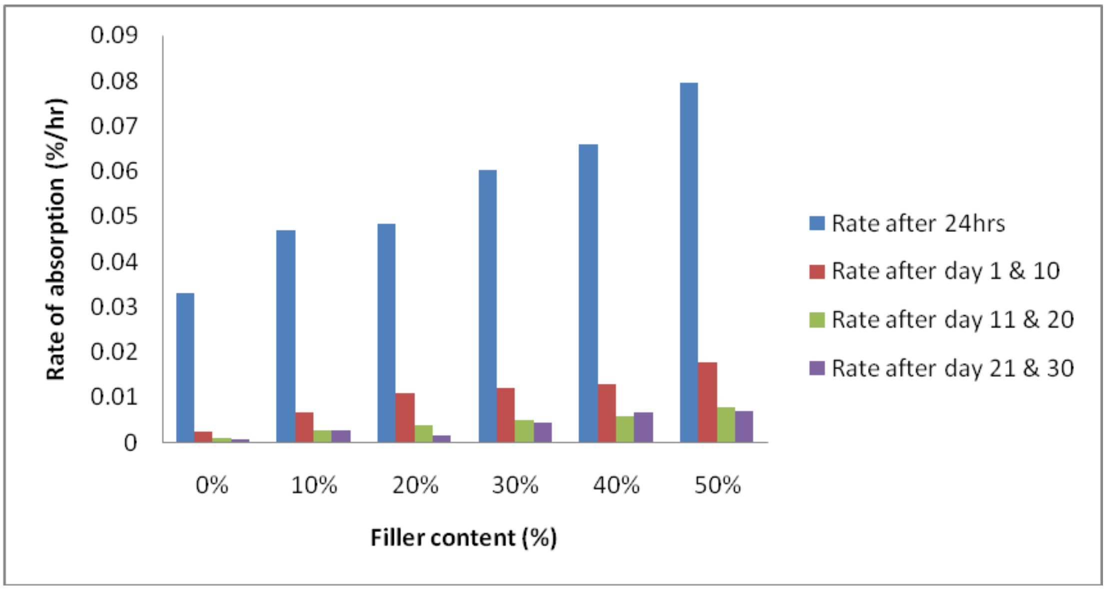

Figure 2: Effect of filler content on rate of absorption of water by date pits/epoxy composite

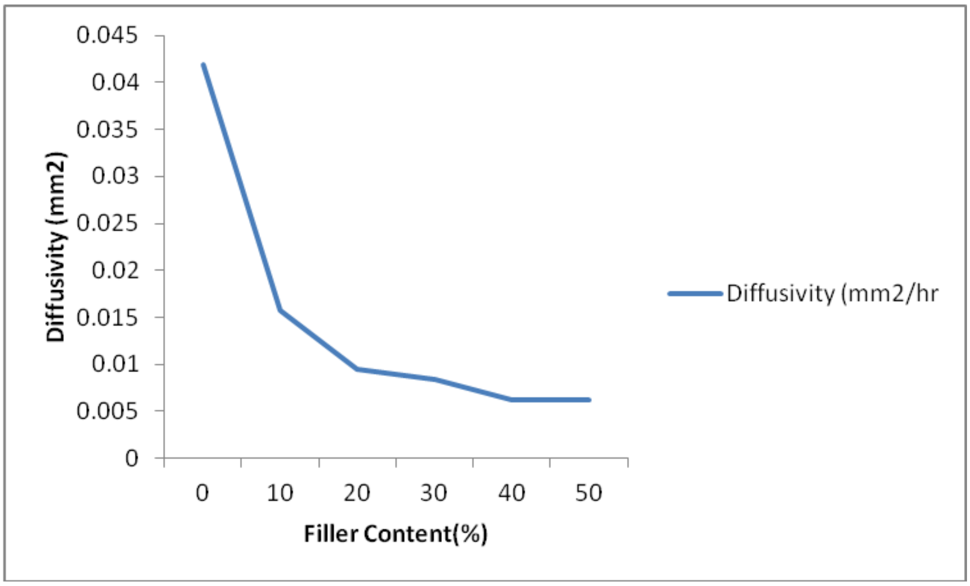

Figure 3: Effect of filler content on diffusivity constant of water in date pits/epoxy composites

From the results as reveal in Fig. 1, water absorption capacity increases as the filler ratio increases. The percentage hydration capacity of date particulate / epoxy (DTP/EP) at room temperature of about 25^{o}C has the following values after 24hours (a day) of absorption as: 1.127, 1.158, 1.444, 1.579, and 1.910 at 10, 20, 30, 40, 50 percent filler content respectively as shownin Table 1, while the neat epoxy composite gives 0.789.

The investigation shows that the absorption continues to increase daily and after 768hours (32 days) the following values were obtained: 3.815, 4.712, 6.476, 7.560, and 9.312 for the corresponding 10, 20, 30, 40, and 50% filler weight content. The daily absorption is primarily due to the hydrophilic nature of the lignocellulosic filler. The neat epoxy composite reached maximum value of 1.605 after 648hours (27days). However, the rate of absorption for the composites was at maximum after the first 24hrs of absorption as reveal in Fig. 2.

Thus, the mechanical properties of polymer composites will be found to decrease with the increase in the percentage of water uptake. The deterioration in the properties such as tensile strength, modulus were explained by the plasticization of the fiber-matrix interface and swelling of the date pits filler as it absorbs moisture thereby decreasing the resistance to deformation that will ultimately lead to increase in the flexibility of the molecular chain, and also increase the elongation at break. One of the most important studies that have been used to predict the absorption behavior of water in a composite is Fick's law of diffusion. It is applied to simple single free-phase diffusion of water into a material, which assumed that the rate of absorption dM/dt is determined by the water concentration gradient dC/dt.

The Fickian mechanism may be explained by one of its postulates, known as Fick's first law: the diffusive flux goes from regions of high (water) concentration to regions of low concentration, with a magnitude that is proportional to the concentration gradient. The equation below describes the diffusion flux J, where D is the diffusivity or the diffusion constant, c is the concentration and x is the position (height) [8].

Fick's first law

Thus

$$\frac{dM}{dt} = -D\frac{dc}{dx}$$

If the rate of water diffusion is written as J

$$\text{Diffusion Coefficient (J)} = -D\frac{dc}{dx} \quad \text{...equation 1}$$

The slower the diffusivity of the specimen with respect to water, the faster the water diffuses into the specimen and consequently the faster the water absorption.

$$\text{Diffusivity (D)} = \pi\left[\frac{Kh}{4Mm}\right]^2 \quad \text{.......equation 2}$$

Equation 2 allows for a one dimensional approach to determine the diffusion constant, where, k is the initial slope of a plot of M(t) versus $t^{1/2}$ i.e. the slope of the linear portion of the graph, Mm is the maximum weight gain (equilibrium uptake) and h is the thickness of the composites.

From equation 2, diffusivity for the various filler loadings are then calculated.

Therefore, water absorption capacity and the rate at which the material absorbs water are crucial factors to be taken into account when considering the effect of water on the composite.

4. Conclusion

The water absorption capacity was found to have maximum value at 50 wt % of filler loading. Thus, the sorption of water increases with increase in filler loading and equally follows Fickian behavior.

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