Zinc Oxide Nano Particles Integrated Kenaf/Unsaturated Polyester BioComposite

Mohammed Mohammed[1], Bashir O. Betar[2], Rozyanty Rahman[1], Aeshah M. Mohammed[3], Azlin F. Osman[1], Muhammed Jaafar[4], Tijjani Adam[5,*], Omar S. Dahham[5], Uda Hashim[6] and Nik Z. Noriman[5]

[1]Center of Excellence Geopolymer and Green Technology, School of Materials Engineering, Universiti Malaysia Perlis, Kangar, Perlis, Malaysia.

[2]Research Center (NANOCAT), University of Malaya, Kuala Lumpur, Malaysia.

[3]College of Health Solutions. Health North Building, Arizona State University, Arizona, USA.

[4]College of Education for Pure Science Ibn-Alhaitham, University of Bagdad, Bagdad, Iraq.

[5]Faculty of Engineering Technology, Universiti Malaysia Perlis, Kampus Uniciti Alam Sg. Chuchuh, Padang Besar (U), Perlis, Malaysia.

[6]Institute of Nano Electronic Engineering, Universiti Malaysia Perlis, Kangar, Perlis, Malaysia.

*Corresponding Author: Tijjani Adam. Email: tijjani@unimap.edu.my.
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Abstract: Increasing need for materials with special features have brought various new inventions, one of the most promising hope for new material with special features and functionalities is composites materials. Thus, this study report an integration of zinc nanoparticles into kenaf/polyester polymer composite to introduce new behavior to the composite. The composite behaviors were compared for mechanical, thermal, moisture absorption and biodegradability properties. Prepared Zinc Oxide nanoparticles entrenched in the kenaf/polyestaer composites net structure through chemical bonds between kenaf/ZnO/polyester resin, existence of ZnO significantly influence the mechanical and thermals properties of composites. Thermal analysis based on (TGA) response revealed the integration of ZnO nanoparticles improved the thermal stability when thermal decomposition temperature beyond 3650 C. The thermal cracking decreased with present of ZnO and increase with kenaf content (layers). The modulus, Tensile strength, break at elongation, flexural modulus, flexural strength and impact strength of the composites with higher content kenaf/ZnO nanoparticle are 560 MPa, 58MPa, 1.8%, 1300 PMa, 68 MPa and 31 MPa, respectively. Thus, addition of kenaf layers and ZnO results in larger mechanical properties enhancement, the results of the contact angle show improvement in wetting of the fibres with addition of ZnO nanoparticles.

Keywords: Polymer composite; thermal properties; mechanical properties; nano-composite; biodegradable polymer; nano; zinc oxide

1 Introduction

Environmental challenges today motivates scientist around the worldwide quest for new and yet biodegradable material [1]. Natural fibres polymer composites which have tendency to support the ability of polymer with sound mechanical and thermal properties yet biodegrade occupy a significant position in the world market [1,2]. The materials ease of manufacturing have allow researchers to use locally introduced inexpensive equipment and materials to produce and study the reinforced composite. Good reinforced polymer composite for different applications are easily produced [3]. The integration of natural materials such kenaf have attracted great interest in the development of low-cost, scalable and robust environmentally friendly composite [4]. The development will allow to obtain biodegradable material with mechanically capable which could fit into various applications. Moreover, the quest of materials based on

natural materials is expected to grow for the next 2 to 3 decades, this mainly due to their environmental advantages the materials offers [6]. The composite has number of advantages over pure petroleum-based product which include light weight, low cost, mechanical strength and thermal stability [7]. The materials will offer various advantages in mechanical and thermal related application which extending to load bearing application, packaging, automobile and euro spaces [8-15]. However, despite these potentials, the natural fibres based polymer composites has many disadvantages, this is mainly due to the hydrophilic nature of natural fiber [16]. Another pressing issue with natural fiber, the materials is having polar orientation which render it low compatibility with non-polar hydrocarbon polymer matrices, this results weak mechanical behavior. Moreover, the fibers absorb moisture from the environment, due to the hydrophilic nature of the fiber which further results in low life cycle and poor interfacial bonding between fiber and matrixes [17-20]. Certain steps have been taken to provide solution to these problems, solution such as modification of the fiber surface by some chemical or enzymatic treatments, addition of coupling agent and using other additives or fillers [21]. However, most of the proposed solution attempted focus on improving mechanical and thermal properties of the composite but the moisture absorption by the fibers which is cause of mechanical and thermal failures are still area of great concern [22-28]. Thus, it is necessary to look for materials that having both ability to provide mechanical and thermal stabilities and can eliminate moisture absorption by the composite [29-34]. Among the materials currently proposed my research communities are semiconductor-based materials such as zinc oxide nano particle [29-33]. The ZnO nanoparticle are highly promising nanomaterial in polymer-based composite application. The materials have potential electronic properties that highly useful for electronic interactions, it has a direct and wide band gap potentially will play an important role in energy interaction and conversion. It direct and wide band gap near-UV spectral region is an advantage that could be used for photoelectronic activities. Generally due the large free-exciton binding energy, the materials show capable of excitonic emission processes even at room temperature [4]. The zinc oxide nanoparticle has been studied by many research communities, it was found that it has manipulative direct wide band gap, a large optical absorption coefficient, a very large exciton binding energy between (55-60 meV), high chemical and thermal stability, good piezoelectric which can be good potential for where atomic vibration is unavoidable[34-37]. Therefore, this study posed to explore this potential by incorporating Zinc oxide into kenaf and unsaturated polyester composite to study UV attenuation of ZnO in the composite to provide water absorption resistance mechanism through observing the composite mechanical, morphological, thermal Properties and water uptakes behaviour with ZnO treatment and kenaf fibre arrangement.

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2 Materials and Methods

2.1 Materials

For the purpose of the reinforcement in the polymer matrix, kenaf fibre was obtained from Rahamatullah Sdn. Bhd (Kedah, Malaysia). The kenaf was in mat form and used without any further treatment. A standard unsaturated polyesters synthetic resin which as a functional matrix in the polymer was supplied by Castmesch Technologies Sdn. Bhd. (Perak, Malaysia). An organic peroxide methyl ethyl ketone peroxide (MEKP) solution in dimethyl phthalate) which provide crosslinks for resin solidification was obtained from Kaumjung Akzo Nobel Peroxide Ltd. (Tianjin, China) by the trade name Butanox M60. Rod shape nano-zinc oxide (ZnO~20 to 60 nm particle size) was purchased from Sigma-Aldrich (M) Sdn. Bhd. (Kuala Lumpur, Malaysia). The nano-zinc oxide (nano-ZnO) with 81.39 g/mol molar mass, 5.61 g/cm³ density, 99.8% purity and unsaturated polyester (UP), and MEKP UP had a hazy pinkish colour with a gel time of 18 min to 23 min at 25°C with 2% MEKP. The density of the UP was 1.4 g/cm^3 with a specific gravity of 1.12 g/cm^3 and a volumetric shrinkage of 8%. The MEKP was colourless in appearance with a density of 1.15 g/cm^3 with a melting point of -8°C and a boiling point of 109°C.

2.2 Methods

Prior to the treatment of the kenaf, it was cut to 20×20 cm dimensions (four layers), this followed by compressing them using compress machine at 90°C for ten min, the process of compressing was done to

remove air between the kenaf fibres. The ZnO was prepared, the preparation consists of preparing 5% zinc nano concentrated solution for the KF to be immersed for 15 mins at room temperature. The treated kenaf was washed to remove larger particles and unwanted foreign elements, this process was done by rinsing the KF thrice with DI water containing two drops of IP and dried in an air-dried for 2 h. The composite was prepared, and the preparation was first conducted by arranging the layers of treated kenaf fibre in a mould and hand lay up the resin (unsaturated polyester + hardener (2%)) and with ratio of 30:70 wt% (fibre to resin) to it. Resin impregnated into kenaf fibre mat via hand lay-up method. Where in impregnated into 4 layers to make pure kenaf is the top composite after that compressed the composites for 10min without heating at 5 MPa and allowed it to cure at room temperature for 24 h. This followed by separating it from mold using hack saw. The prepared composite was measured and cut to 2.5 × 20 cm sizes and further, it was prepared for the characterization after the initial characterization, the biodegradability study were performed in accordance to "ASTM D1435-13, "Standard Practice for outdoor of plastics characterization", ASTM International, West Conshohocken, PA, 2013. The water uptake study was conducted based on ASTM D570 standard in which the sample with the dimension of $130 \times 12 \times 3$ mm^3 was immersed in distilled water for 60 days at room temperature. Accordingly, the specimens were placed in individual capped test tubes and were weighed at regular time intervals. Specifically, the retrieved specimens were wiped with the absorbent paper, weighed and immediately placed back into the water medium after a weigh-in. The physical characterization was conducted with a scanning electron microscope (JSM6400; JEOL Ltd., Tokyo, Japan) and mechanical testing for the tensile and flexural tests were performed in the Kubang Gajah Laboratory, Universiti Malaysia Perlis, *via* a universal testing machine (Instron 5569; Instron, Norwood, MA, USA) based on "ASTM D638-14, "Standard Test Method for Tensile Properties of Plastics", ASTM International, West Conshohocken, PA, 2014".

3 Results and Discussion

The results section started with description of the physicochemical properties and photoactivity of ZnO. The ZnO generally available in its naturally form in the Earth's crust, it consists of two main crystalline forms, namely, wurtzite and zinc-blende. For the purpose of the study, the wurtzite form is used due to relative stability with low refractive indices. It has a wide-band, and in origin, n-type semiconducting material. The ZnO in wurtzite form have the 3.22 eV, i.e., 0.1 eV lower than for zinc-blende (3.32 eV) according to Smijs and Pavel (2011) [4]. The wurtzite shown mechanical anisotropic behaviour, its maximum elastic moduli at <111> and minimum elastic moduli at <001>. This very important behaviour in polymer composite general mechanical properties. The shear moduli in the wurtzite, Poisson's ratios at the planes containing <001> axis are anisotropic, and the maximum value is 0.31 which is located at the directions vertical to <001> axis the property is an ideal value for the materials in load bearing applications. Moreover, apart from the physicochemical properties, the materials have good photocatalytic activity [32]. Photo-induced reactions of ZnO have gained much attention and have proved to be useful in environmental applications. The effect of the photo-induced reaction brings the formation of superoxide anion radicals ($O_2^{\cdot}$) and hydroxyl radicals ($^{\cdot}OH$) in the presence of light. There, there ZnO is an ideal choice for incorporating into natural fibre such as kenaf. Moreover, the kenaf fibres are complex heterogeneous lignocellulosic natural fibre, the fibres generally consist of cellulose, hemicellulose, and lignin. The fibre is hydrophilic in nature due to considerable number of presences of large number of hydroxyl groups [4]. The high present of this radicals render the reaction incompatible with hydrophobic matrices such polyesters. Therefore, it necessary to search for solution, thus, the proposed solution in this study is to provide rug surface modification via ZnO and surface modification with ZnO nanoparticle will resolve the issues of the hydroxyl groups and improves the compatibility between kenaf fibre and polyester matrix as well as reducing the hydrophilicity of the fibres with the Zn^{2+} ions which. The strategies for improving the fibre-matrix interaction is based on functionalized fibres, with a backbone that should be compatible with the matrix, and the functional groups attached to this backbone that can interact with the reinforcements too from the matrix. Compatibility with the matrix is often achieved by using polymers and fibre backbone [5]. The polymer interaction with hydrophilic reinforcements kenaf is based on covalent bonds via oxygen or

hydrogen bridges between the functional groups of the coupling agent and on the fibre surface like OH-groups Fig. 1.
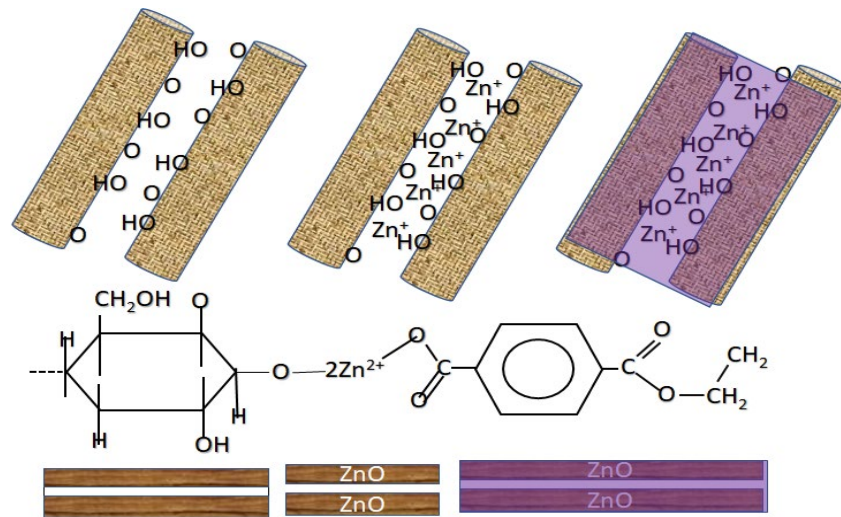

Figure 1: Illustration on presumed reaction of kenaf, ZnO with polyester
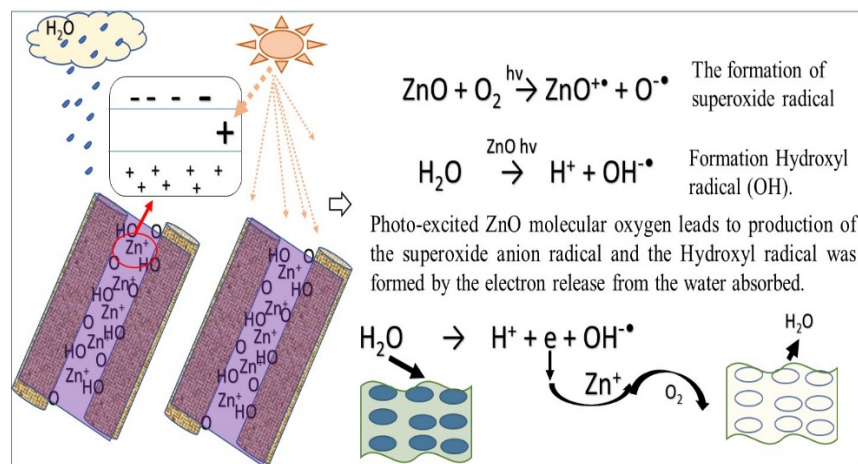

Figure 2: Photoactivity of of ZnO on components of kenaf/polyester composite

The formation of superoxide radical and Hydroxyl radical (OH). The formation of these radicals resulting from the photo-excitation of ZnO. An electronic transfer from photo-excited ZnO to molecular oxygen leads to production of the superoxide anion radical. The Hydroxyl radical was formed by the electron release from the water absorbed by the kenaf fibre. The reoxidation of the ZnO back to Zn^+ ions, the process can start again Fig. 2.

The characterization and analysis of prepared zinc nano particle of the ZnO nanoparticles as shown in the Fig. 3. The FESEM images of the zinc oxide nano particle. The surface morphology of the particle which was obtained by hydrothermal growth of ZnO nanoparticles are shown in both FESEM and TEM. The size between 20 to 60 nm.
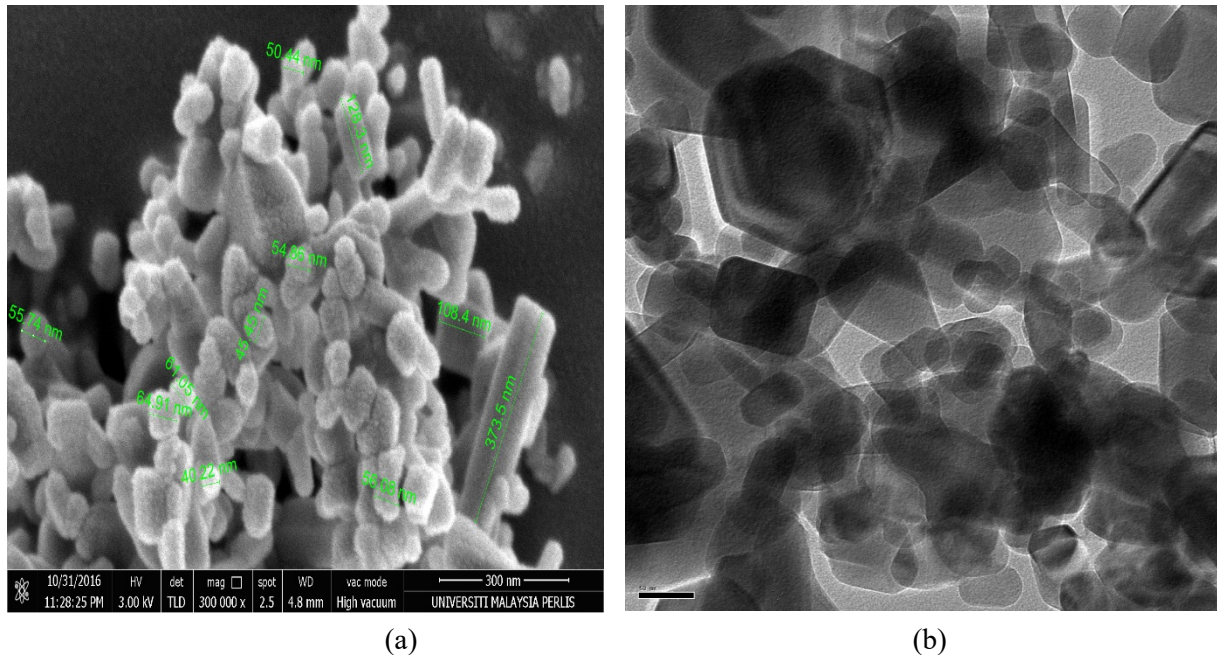
Figure 3: The zinc oxide nanoparticle (a) FESEM (b) TEM

The Fig. 3 revealed the existence of both zinc and oxide. The (ZnO) nanoparticle is increasingly becoming an interesting nanomaterial which give very good thermal conductivity. The crystal structure of the materials comes in the wurtzite structure, and its bonding is a mix of ionic and covalent which provide good melting point, modular strength, temperature and chemical stability. Zinc oxide is the most piezoelectric of all materials and is widely used.
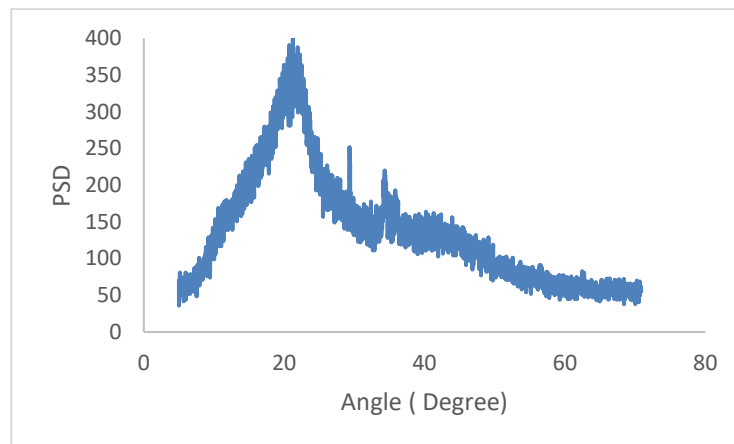

Figure 4: The XRD of pttern of the ZnO nanoparticles

The Fig. 4 shows the XRD patterns of ZnO, the broad smooth hump between 5 and 35 (θ) in the diffractogram in Figure show the characteristic feature of nano size material, indicating behaviour the crystalline structure it shows like amorphous, random rod like, ordered particle of homogenous structure which have potentially capable of photo adsorption. This augment in crystal organization would affect the available surface area, resulting in restriction of adsorption capability.
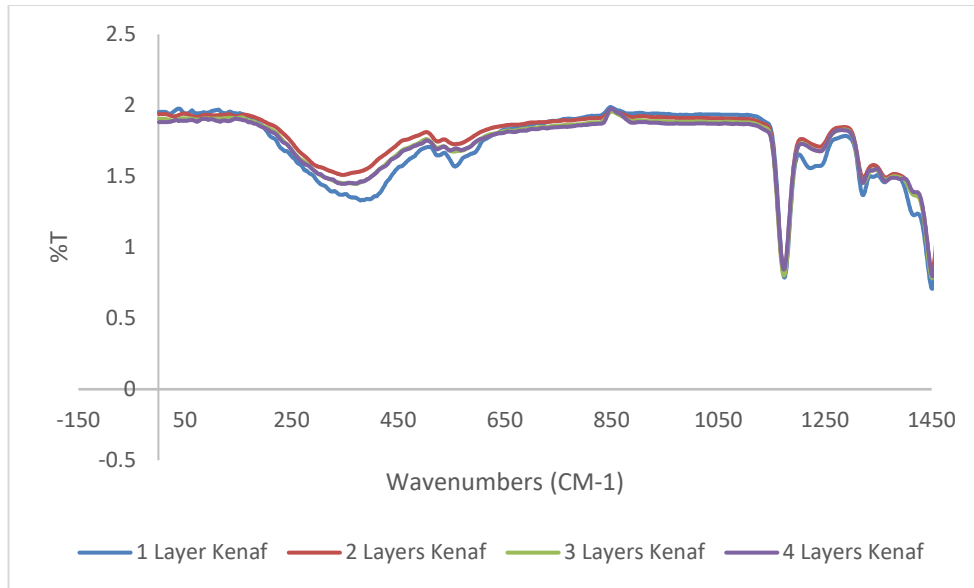
Figure 5: FTIR spectrum of the untreated kenaf specimens composite of 1, 2, 3, 4 layers arrangement

Fig. 5 shows the FTIR spectrum of the four (4) specimens composite which were prepared with kenaf fibres with 4 different layers arrangement. The peak at 1100 cm^{-1} was assigned to O-H stretching vibration of hydroxyl functional group; all the fibre compositions have this functional group as can be noticed. The peak at 1450 cm^{-1} was attributing to symmetric stretching groups which is hemicelluloses. The peak at 1300 cm^{-1} was the C=O ester stretching vibration, this is an indication of present of lignin functional group. Kenaf 1 layers showed more peaks than the others, it can be seen peak at 350, 550, 1100, 1300 and 1450 and it had the highest peaks and the kenaf 2 layers had the second-highest show the present of low lignin because 1 layer does not dominate the composite. The 3 layers and 4 layers show diminishing peaks this is attributed dense aromatic ring vibration and stretching which caused as result of the more present of the lignin, similar results was found in [38].
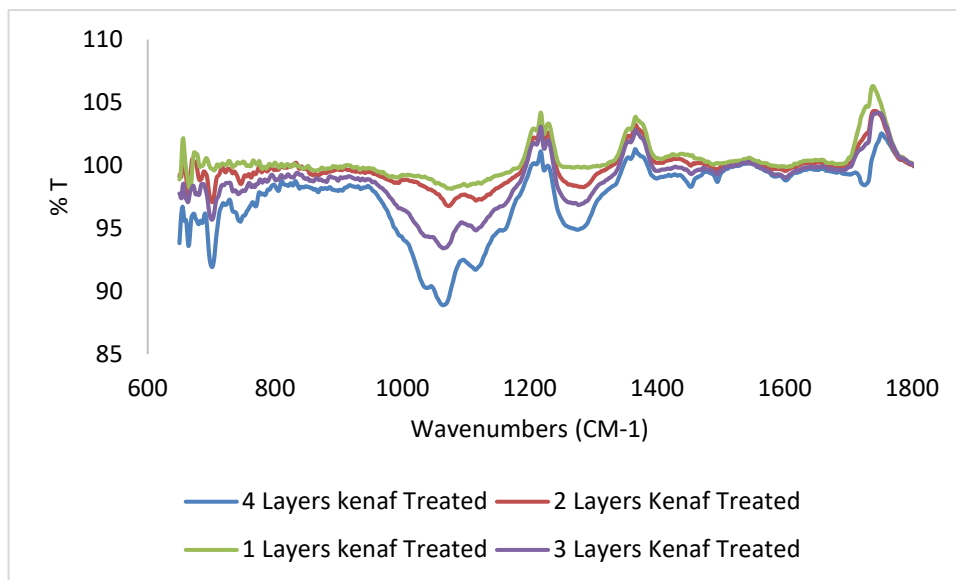

Figure 6: FTIR spectrum of the treated kenaf specimens composite of 1, 2, 3, 4 layers arrangement

The FTIR analysis was conducted to study the characteristics of the kenaf fibres layers after treatment as shown in Fig. 6. It can be observed the shift on the spectra compared to the pure kenaf arrangement. The shaped peak at 1100 cm^{-1} which appears all samples with 4 different spectra is attributed to the O-H frequency of each sample, whereas the peaks at 1400 cm^{-1} predominantly arise from C-H stretching. The peaks at 1200 cm^{-1}, 1350 cm^{-1}, 1830 cm^{-1} correspond to ester carbonyl vibrations from groups in lignin, this observation was equally made by Loh et al. (2015) [38]. Interesting to note that with the ZnO treatment, there was a decrease in the intensity of these peaks from the 1 to 4 layers, indicating that most of the lignin void inter fibril has been block by the increase in the layers and with the treatment. stretching peaks are detected at 1700 cm^{-1} which correspond for untreated fibre, this is attributed to the carbonyl group of the acetyl ester in hemicellulose and the carbonyl aldehyde in lignin. The present of this peaks 2800 cm^{-1} after the treatment may be due to the existed of lignin and hemicellulose which emphasis ZnO does not affect the chemical composition of kenaf fibres. However, after the treated kenaf fibre, the disappearance of the vibration peak at high wave numbers corresponds to C-O vibration is also attributed to the engagement of lignin ions with reaction with ZnO. The Fig. 7 shows the differences in surface profile between the ZnO untreated and treated kenaf polyester composite. The ZnO particle on the treated fibre surfaces were evidently observed after the ZnO treatment as shown in the comparisons in Figs. 2(a) until 2(h). The treated kenaf fibres profile revealed the existence of the particle and which was well dispersed. Here the treatment of the kenaf surface was successfully done. With this, the treatment is expected to provide water absorption resistance to the sample, improve mechanical properties of the composite by providing coupling tendencies via adhesion between kenaf and the polyester. Moreover, the treated kenaf fibres expected to reinforce polymer composites required mechanical properties and which exhibit low water absorption as the zinc oxide particle is highly hydrophobic coupled with nature of the treatment, the treated is expected to result in the blocking of water passage to the fibre intermodular chain and equally provide photo activities that will repel water surface.

It can be concluded Fig. 7 shows typical SEM images of unmodified and ZnO modified kenaf, it can be seen clear, morphological differences between the two kinds of samples. All the ZnO individual particle can be seen and distinguished clearly.

The SEM micrograph for the flexural fractured kenaf fibre composites, four (4) armament of the kenaf fibre composites were compared with the 1 layer to 4 layers fibre volume fractions test were tested, the kanaf underwent the flexural, due to the flexural load, the interphase break is found at the cross section of the composite as shown in Fig. 8. More fibre pull-outs are observed in the through our from the 1 layer to 4 layers fibre composite. The layer composite and two layers show less pull-out of the fibres due to the less fibre accumulations in the composites. However, in 3 and 4 layers composite fibre undergoes the minimal breakage due to the predominance of fibre pull-outs. Individual fibre delamination is not found so frequently in the zinc treated composite. Flexural strength is very less due to the poor stress transfer between the fibre and the matrix at the interphase region of the composites. But at 1 layers flexural fractured specimen, the fibre pull-outs behaviour of the composite occurs rarely when compared with the 4 layers. The 1 layers fibre composite have the higher fibre breakage than the 4 layers fibre composites. This indicates that there is a good interaction between the fibre and matrix at the interphase. Stress transfer between the reinforcement and the fibre is appreciable, which is also evident from the flexural strength values at 4 layers. Fibre breakage occurs very frequently in both tensile and compressive regions due to the less fibre pull-outs and particularly higher fibre accumulation leads to the better adhesion at the interphase region. Due to the minimal fibre pull-outs in the composites, the fibre breakage is higher and the individual fibre delamination is also predominant due to the same reason.
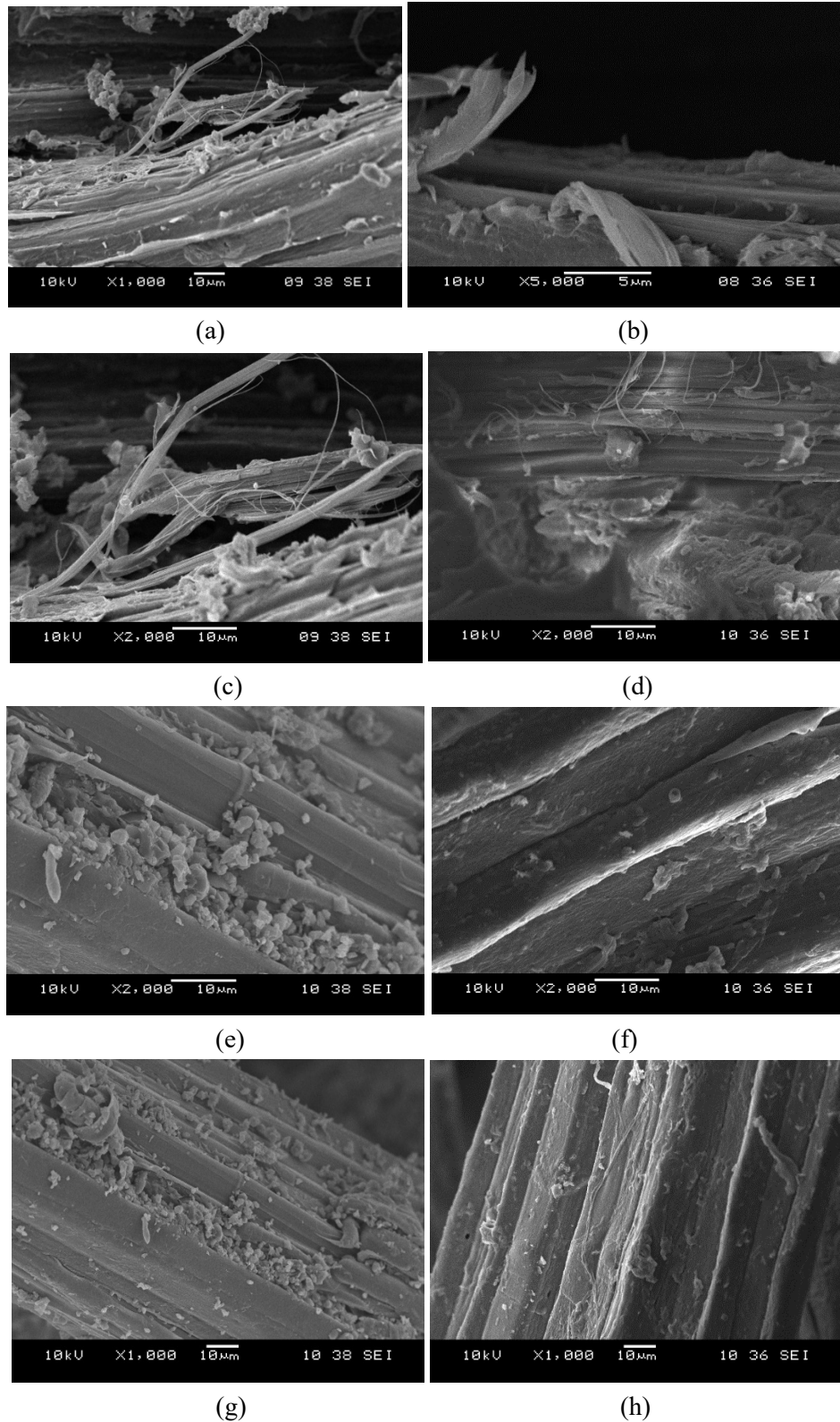
(a)   (b)

(c)   (d)

(e)   (f)

(g)   (h)

Figure 7: SEM micrographs of ZnO treated and untreated kenaf surface (a) 1 layer treated (b) 1 layer untreated (c) 2 layers treated (d) 2 layers untreated (e) 3 layers treated (f) 3 layers untreated (g) 4 Layers treated and (h) 4 layers untreated kenaf
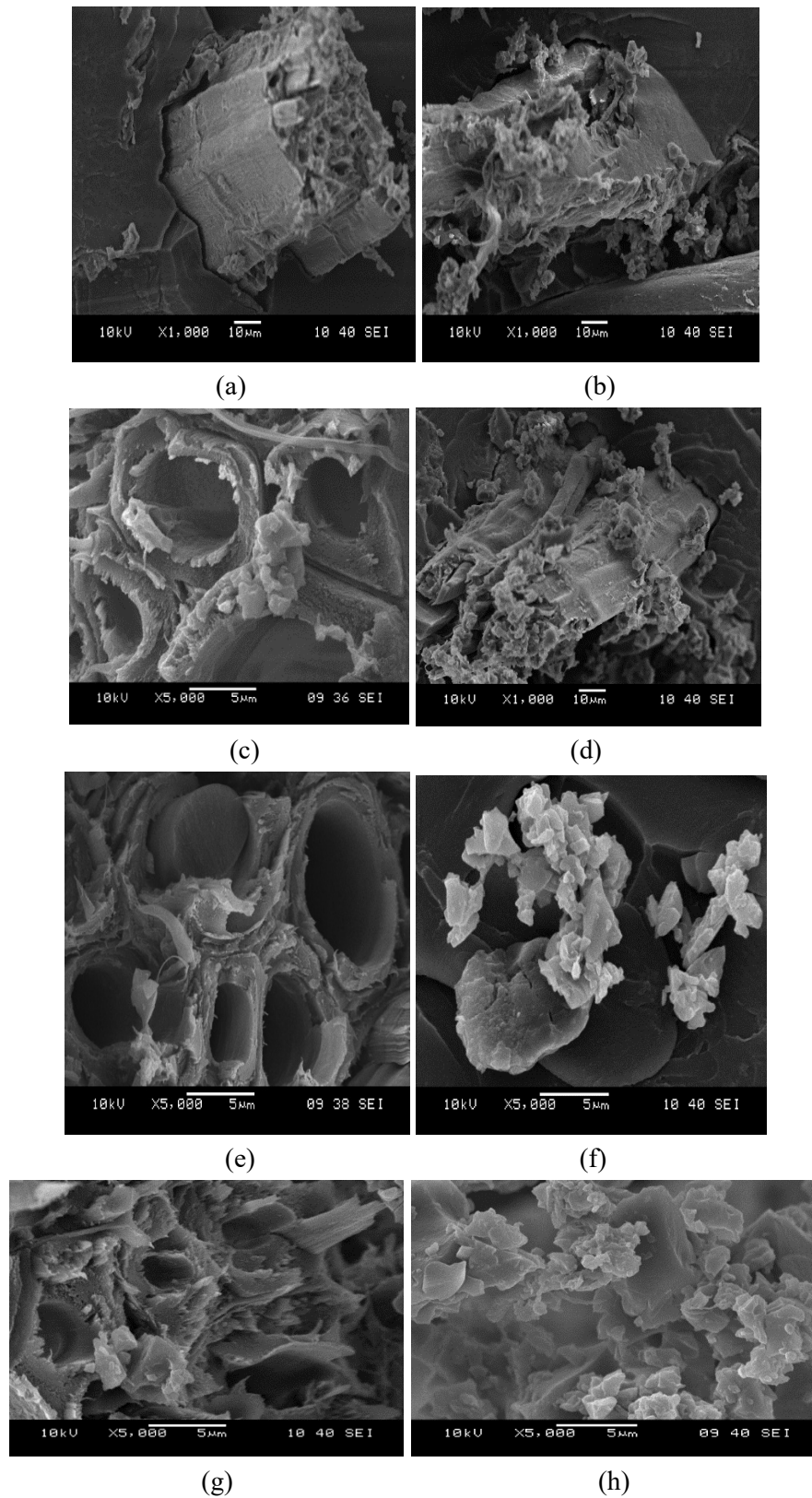
Figure 8: SEM micrographs of ZnO untreated and treated kenaf after flexural test surface (a) 1 layer treated (b) 1 layer untreated (c) 2 layers treated (d) 2 layers untreated (e) 3 layers treated (f) 3 layers untreated (g) 4 Layers treated and (h) 4 layers untreated kenaf

3.1 Thermal Properties

Fig. 9 shows TGA test results of kenaf fibre with 4 different arrangements of kenaf layers. It assumed that oxidative branching and crosslinking were the prevalent degradation mechanisms in the analysis of the thermal properties of the kenaf fibres. The fibre was relatively stable below 300°C. The volatilization of kenaf fibre started at 325°C. Beyond 325 until 390 the kenaf experience shape degrease in mass, this is likely as results of the fragmentation of cellulose network, it expected the most gaseous components such as water, carbon dioxide, methane, phenols and cresols are released during between this ranges of the temperature. However, the thermal decomposition temperature of higher kenaf content was lowest compared to lower content. This is likely attributed to many OH groups are excess in the 4 layers kenaf compared to the lower layers which does not require much thermal energy to degrade the fibre.
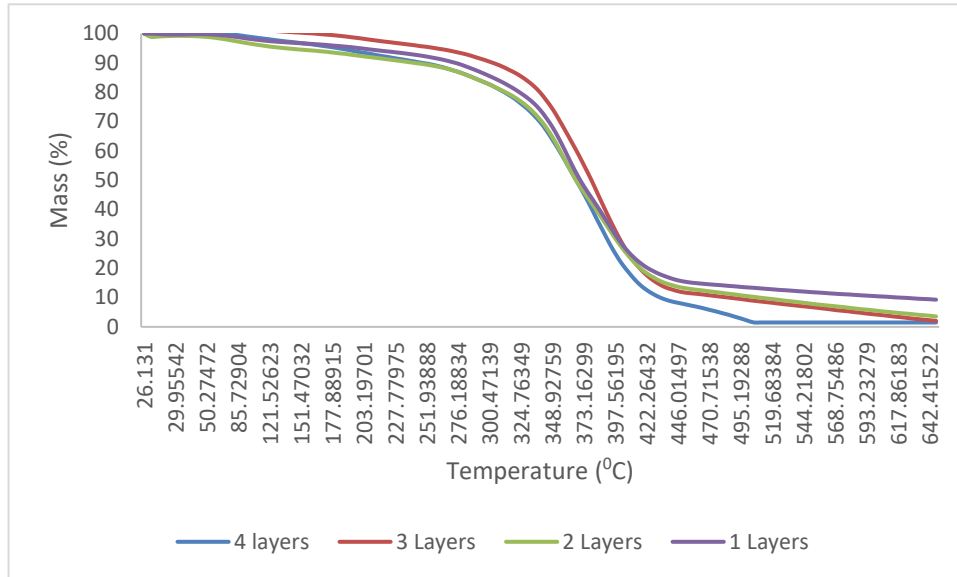

Figure 9: TGA test results of kenaf fibre with 4 different arrangements of kenaf layers
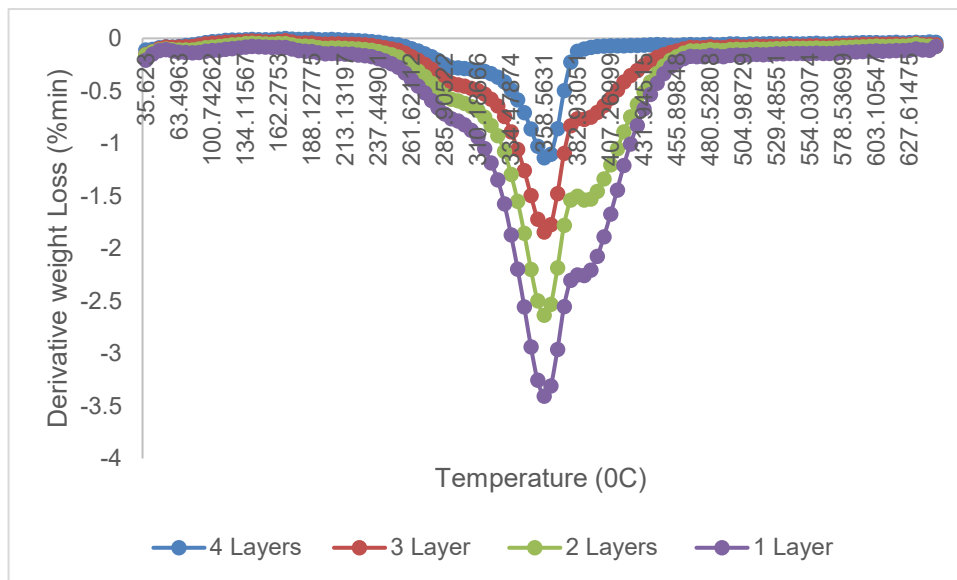

Figure 10: Thermogravimetric profiles of containing 1 layer kenaf, 2 layers kenaf, 3 layers kenaf and 4 layers kenaf derivatives weight loss of the systems

In conclusion, the Fig. 9, summaries thermal behaviours of the kenaf/ZnO/Polyester composite were investigated using the 20% weight loss observed at 251°C. The highest weight loss was observed with 4 layers kenaf this is attributed to the more water being H_2O molecule removed this further emphasis how kenaf is so hydrophilic. All the samples pronounced final weight losses beyond 600°C. This indicate Kenaf/ZnO/polymer nanocomposites significant improvement in thermal stability as compared with kenaf/polymer.

Fig. 10 shows the thermogravimetric profiles of containing 1 layer kenaf, 2 layers kenaf, 3 layers kenaf and 4 layers kenaf derivatives weight loss of the systems. As expected, different kenaf arrangement show kenaf derivative loss decrease. The addition of kenaf fibres layers composite decreases the temperature at which the onset of degradation occurs. This is also reflected in the derivative curves where the maximum rate of degradation for the 1 layer kenaf to 4 layers kenaf occurs at the temperatures of 237, 262 and 271, 271°C respectively. The second degradation temperature of the composite containing all kenaf arrangement was observed at approximately 3100°C with a small but noticeable peak this might be due some impurities. Normally, natural fibres degrade at lower temperature, However, another possible reason might be due to the degradation of a non-cellulosic substance such as lignin.

3.2 Mechanical Properties

The Fig. 11 shows the mechanical behaviour of the kenaf/ZnO/polyester composite with kenaf layers and ZnO treatment. The observation was made on the tensile properties of the kenaf/ZnO/polyester, the figure 11a show the young modulus of the composite, the young modulus increased significantly, from 350 MPa of the 4 layers kenaf to 354 MPa as the number of the layers increase from 1 to 4. The young modulus increment was due to the increased in the rigidity of the composite with layers getting thinner. Moreover, the increment was observed when each layer is added the Young's modulus increased the similar claimed was reported by Sayeed et al. (2014) [32]. The largest increment was found in the 4 layers kenaf was added, that is, an increase of up to 3-fold compared with the 1 layers. One more likely explanation is the shape increase in the aspect ratio of kenaf than that of polyester might be responsible for this behaviour [2] in their study gave a similar explanation. The issues of polymer adhesion to natural materials was a great concern to the researchers working in the field as the compatibility between this materials component is giving serious problem to the researchers. However, in this study, the good adhesion between the kenaf and matrix was obtained this achieved was likely as a result of the present of the ZnO nanoparticle which enhance the molecular interaction between the two materials. Fig. 11(b) show the tensile strength of the samples. The values gradually increased with an increase in the kenaf layers 20 to 55 MPa (1 layer to 40.4 MPa (4 layers kenaf loaded). In general, the tensile strength obtained under a large deformation is more sensitive to crack defects than the Young's modulus acquired at the initial deformation. The visible interfacial cavities between the two phases of kenaf and polyester in the SEM results above was evident. Therefore, the cracks eventually propagated under load, which caused the kenaf/polyester blends to have lower strength at higher amounts of fibres. The interesting to note that there is a continuous reduction in breaking elongation with the stack of the kenaf fibre layers as can be seen in Fig. 11(c). This because kenaf fibre have low breaking elongation and increase the layers of kenaf decrease the breaking elongation composite. The Fig. 11(d) shows the flexural response of the composites, flexural test subjected the deformation on the composite in all direction these include tension compression and shearing occurs at the same. In this case, it expected that this test subjected the composite to uniform stress. The flexural modulus properties of treated and untreated composites are shown in Fig. 11(d). Flexural modulus showed a similar trend as tensile modulus. When the fibre content increased from 1 to 4 layers the flexural modulus of both treated and untreated composites increased. The flexural strength properties of kenaf treated and untreated with ZnO are shown in Fig. 11(e). The composite was tested with 4 fibres arrangement. As expected, it does not show similar trend with tensile strength, the incorporation of kenaf fibre layers did not show much different for flexural strength of the composites in all samples. Fig. 11(g) shows the result of the impact strength for treated untreated kenaf composites with function to kenaf fibre layers. The results revealed that the use of kenaf fibre resulted in a reduction of the impact strength of the composites. Moreover, a continuous decrease in impact strength also can be observed as the fibre composition was increased from 1

to 4. Inani et al. explained the reason of this behaviour which they claimed that energy absorbing mechanism depends on the interfacial interaction between fibre and matrix.
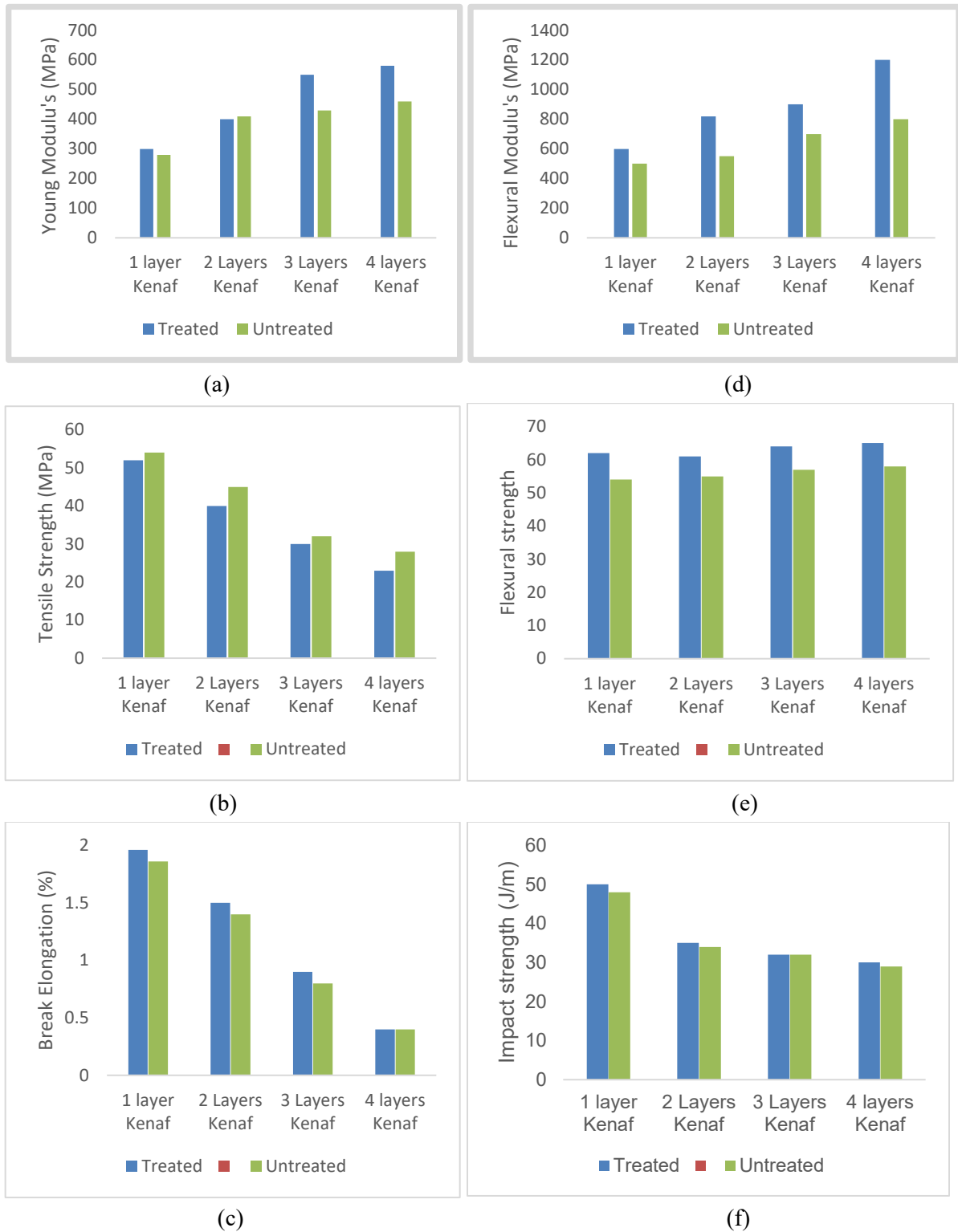

Figure 11: Comparison results of mechanical properties of treated and untreated kenaf reinforced composites with respect to the kenaf layers stack (a) Young Modulus (b) tensile strength (c) Break Elongation (d) flexural modulus (e) flexural strength (f) Impact strength

3.3 Water Uptake Test

The Fig. 12 shows the water absorption test of the treated zinc oxide nano polyester composite, with four different layers of kenaf armament all the arrangement is done by 5% concentration of zinc oxide nano particles. The 1 layer and 2 layers kenaf show the capability of water resistance compared to other two arrangement of the 3- and 4-layers Zinc oxide nano particle filled composites. It can be observed that the water uptake for the lowest kenaf content was the lowest after being immersed in water medium for 30 days the phenomena is attributed to its nonpolar of polyester and hydrophobicity of ZnO nano particle. The weight gain of the composite equally confirmed that, 4 layers composite arrangement show that it gains 40% weight gain after the water immersion process. This is due to the relatively high-water uptake capability of the hydrophilic nature of the kenaf, accordingly might be due the content of the non-polar polyester and hydrophobic (ZnO) are low in the 4-layer kenaf specimen. This claimed was equally reported by Lee et al. (2017) [1] in the study "Composite properties and biodegradation of biologically recovered P(3HB-co-3HHx) reinforced with short kenaf fibres" which it was anticipated that , the kenaf is hydrophilic and absorb water, the study claimed that the addition of kenaf into "P(3HB-co-3HHx) and LDPE significantly increased the water uptake profile of the composite materials. This can be well explained by taking into consideration the hydrophilic nature of the kenaf which allows the water molecules to more easily diffuse in the interfibrillar spaces of the plant structure giving rise to the weight gain".
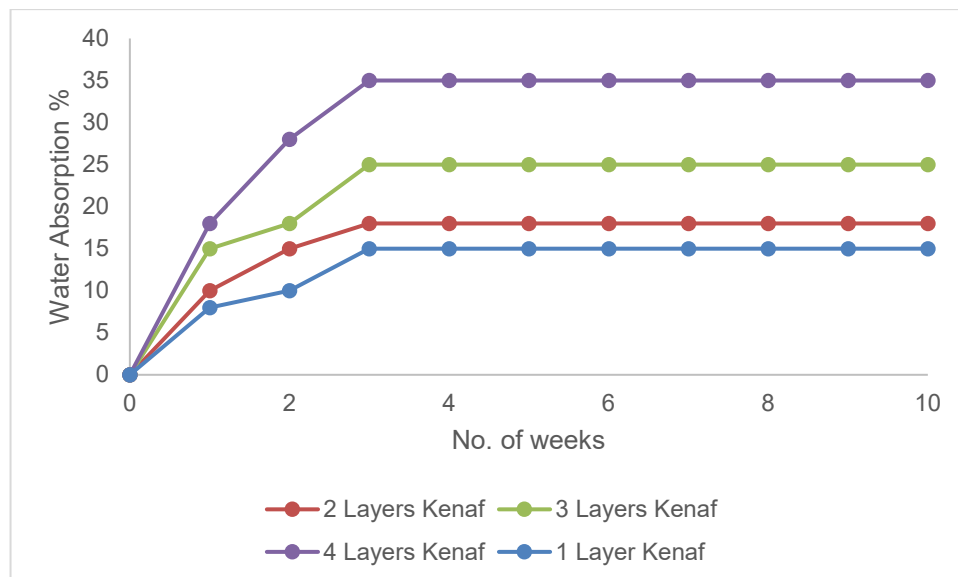

Figure 12: Water uptake test results

3.4 Biodegradability Test

The biodegradability of polymer best composite is currently considerable interest as a result of quest of obtaining highly environment friendly that could replace the plastic material threat to the green environment. The biodegradable materials are expected to naturally undergo delaying in an or in soil when exposed. It is believed that environmentally friendly composites it under go degradation anaerobically in the presence of water and aerobically by the microbial population, this claimed equally reported by the Lee and the team, 2017 published article [1]. In order to understand degradability of kenaf/ZnO/polyester composite, it highly paramount to study the behaviour of the materials when being exposed to the outdoor environment. As it revealed in the water absorption, 4 composite specimens were used, namely 1-layer kenaf/ZnO/polyester composite, 2-layer kenaf/ZnO/polyester composite, 3 layer kenaf/ZnO/polyester composite and 4-layer kenaf/ZnO/polyester composite. As expected, the 4 layer kenaf/ZnO/polyester composite composites displayed a higher weight loss percentage compared to the other three (3)

arrangement higher degree of degradation in soil. This illustrate, the microbial attack in 4 layers kenaf/ZnO/polyester composite is highest compared to other because the highest kenaf contained, as explained in the water uptake, the moisture uptake in the soil by the 4 layers kenaf/ZnO/polyester composite gave room to the highest breeding of microbial within the composite. Additionally, it was found that, as the kenaf content is decrease the weight loss decrease. However, when clearly observed the degradation was very slow at the first week as all the composite gave little weight, this due to the fact that, the biodegradation take place in stages, it initially debonding of the intermodular chain of the cause as result of the leaching of water-soluble substance .
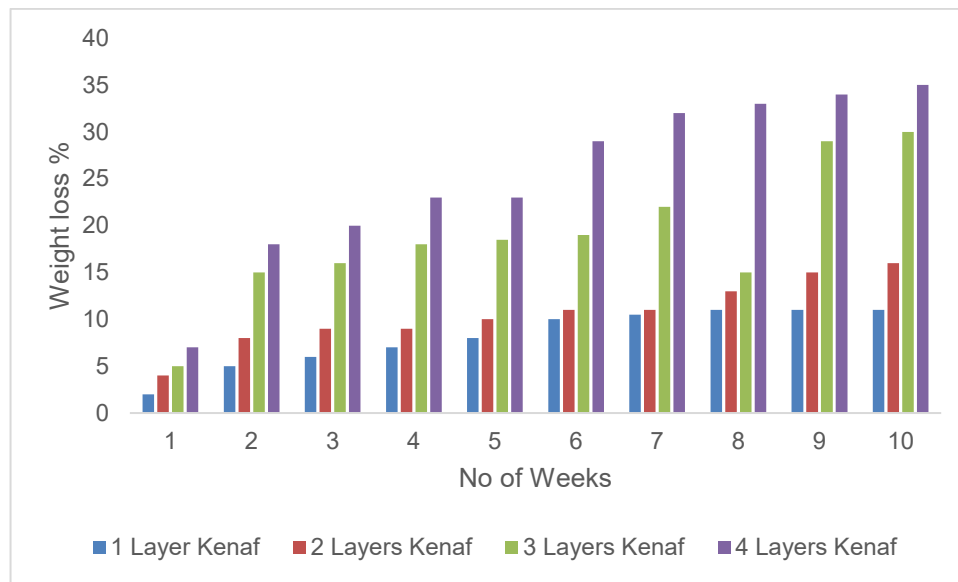

Figure 13: Biodegradability test results

4 Conclusion

The paper presents a research work on kenaf/ZnO/Polyester composite. The reinforced with 4 different kenaf mat stacked arrangement have been successfully prepared using lay hand compressed moulding technique. The surface of the kenaf fibres have been modified using ZnO nanoparticles. The composite show increasing the kenaf layer stacked improve the tensile strength, tensile modulus, flexural strength, and flexural modulus. Moreover, the break elongation reduced with an increase with kenaf mat stack. The effect of stacking sequence of kenaf layers has shown good tensile and flexural moduli improvement of 3 and 4 layers stacked armament. However, it was found the water update is at its highest with the highest kenaf arrangement it show the fibre hydrophilicity. Fortunately, the water uptake drastically reduced with the treatment of the fibre with ZnO nanoparticle. The addition of the ZnO into the composite not only eliminated the water absorption but also improve the mechanical properties and biodegradability of the composite.

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