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Influence of Alkali Treatment and Fibre Content on the Properties of Oil Palm Press Fibre Reinforced Epoxy Biocomposites

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Abstract: **-** In the present work, oil palm press fibre reinforced epoxy composites were developed. The effect of fibre loading varying from 5 wt. % to 30 wt. % on the mechanical properties of oil palm press fibre/epoxy composite was studied. The effect of alkali treatment on mechanical properties of the composites was also investigated. The mechanical properties of treated OPPF/epoxy composites were found to be higher that the untreated oil palm press fibres. Optimum tensile, flexural and impact strengths of OPPF/epoxy composites were obtained at fibre content of 20 wt. % in this work. Hardness, tensile strength and modulus of the composites increased with increasing fibre loading. Alkali-treated OPPF/epoxy composites when compared with untreated OPP fibres at 20 wt.% fibre loading showed an increase of tensile strength by 18.79 %, flexural strength by 15.15 % and impact strength by 18.21 %. The removal of hemicelluloses and other impurities with alkali treatment resulting to higher crystallinity of the OPPF could be responsible for these observations.

Keywords: **-** *Oil palm press fibre, epoxy resin, alkali treatment, mechanical properties, composites.*

I. INTRODUCTION

Biocomposites are material composites in which one of its phases either matrix (polymer) or reinforcement/filler (fibres) comes from natural source (Hassan et al., 2010). A proper combination of a plastic matrix and reinforcing fibres gives rise to composites having the best properties of each component. Plastics are known to be soft, flexible and light weight when compared with fibres, however, their combination yields a high strength to weight ratio to the emerging composite. The properties of composites are dependent on those of the individual components and on their interfacial compatibility. Adequate matrix fusion to enhance thorough fibre impregnation, formation of strong fibre/matrix interfacial bonding, and matrix-to-fibre stress transfer efficiency are vital requirements for the manufacture of reliable, eco-friendly natural composites that can exhibit better mechanical properties and withstand environmental attacks (Malkapuram et al., 2009).

Natural fibres have specific advantages over conventional fibres and also have won the hearts of material scientists, researchers and industrialists for the past decades. Apart from being biodegradable unlike the conventional fibres, low density, low cost, specific properties comparable to those of conventional types, ease of separation, carbon dioxide seizure, non-corrosive, reduced tool wear, reduced dermal and respiratory irritation (Mohanty et al., 2002; Singha and Thakur, 2008), have aroused the interest in the utilization of natural fibres using varied synthetic and natural polymeric materials. However, natural fibres suffer some serious limitations. The polar nature of natural fibres creates incompatibility problems with many synthetic polymers. Bogoeva - Gaceva et al. (2007) has reported other demerits of natural fibres such as poor resistance to moisture, limited processing temperature, and low dimensional stability. Based on this, various chemical treatments have been done to improve adhesion or interfacial bonding between natural fibres and synthetic polymers (Li et al., 2007). These will inevitably enhance the basic properties of natural fibres reinforced polymer composites (Arif et al., 2010; Aranjo et al., 2008).

Alkaline treatment, bleaching, acetylation and steaming are such various processes applied to improve fibre-matrix interaction (Das et al., 2000; Shukla and Pai, 2005; Corrandini et al., 2006).

The alkaline method is an effective way to improve the properties of composites reinforced with natural fibres (Rosa et al., 2009). Sinha and Rout (2009) reported the improvement in mechanical properties of alkaline treated jute fibre composites. Bisanda and Ansell (1991) studied the effect of silanes on properties of sisal-epoxy composites and reported an increase in compressive strength. Rout et al., (2009) studied the effect of 2 % alkali treatment on coir fibre-polyester composites and reported considerable improvement in tensile properties. Huda et al., (2008) in their study, observed that surface treated fibre reinforced composites showed better mechanical properties than the treated fibre-reinforced composites. Similarly, fibre surface modification treatments are found to be effective in improving the properties of composites with natural fibres such as oil palm fibres (Sreekala and Thomas, 2003), Sugar palm fibre (Dandi et al., 2011) and pineapple leaf fibres (Thee popnatkul et al, 2009).

Oil palm press fibres (OPPF) are used as reinforcement materials in this present study. They are one of the waste products obtained from the oil mill during palm oil extraction processes. These fibrous residues are got after the oil is separated from the fruits and account for 10 – 15 % of the fresh fruit bunch. A good source of energy to run the oil mill plants when mixed with other waste products such as kernel shells and empty fruit bunches (Pickard, 2005). The ash obtained by burning OPPF does not contain adequate nutrients to be used as a fertilizer and dumping creates an environmental pollution. However, its incorporation in concrete as a cement replacement has been studied (Pickard, 2005). Epoxies are important class of thermosetting polymer which are greatly used as materials for fibre-reinforced composite materials and structural adhesives (Shangjin et al., 2001; Zhikai et al., 1997). The role of matrix is to keep the fibres in a desired location, orientation and to effectively transfer the stress to fibres (Goud and Rao, 2011). 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. (Goud and Rao, 2011). The present study investigated the effect of fibre concentration and alkali treatment on some mechanical properties of OPPF/epoxy composites.

II. MATERIALS AND METHODS

Materials

Oil palm press fibre (OPPF) was obtained from Ada Palm Industry, Ohaji, Imo State, Nigeria. Commercially available epoxy resin CY-230, hardener HY-951 mould releasing agents and NaOH pellets used were purchased from a local supplier in Benin City, Edo State, Nigeria.

OPPF Preparation/Treatment

To leach out the remaining residual oil from the OPPF which was retained after processing, "wet extraction" method that used hot water as described by Vijaya et al., (2013) was used. The fibres were thoroughly washed with distilled water to further remove impurities followed by sun drying for five days. The dry fibre was then treated with 5 % solution of NaOH for about 2 h to avoid fibre damage. The fibre was later washed with distilled water to remove excess of NaOH and dried at 80°C for 12 h.

Composite Preparation

Epoxy and hardener were mixed in a container and the OPPF was added and stirred well for 8 - 10 mins. The thoroughly mixed mixture was poured into the mould cavity of known dimensions already coated with mould releasing agents and allowed to cure at room temperature. Composites with various OPPF contents (5, 10, 15, 20, 25 and 30 wt. %) were obtained.

Testing of the composites

The test samples were cut out from the composites and were tested according to ASTM standards. Tensile testing was done as per ASTM D638 using a universal Shimadzu tensile machine at a crosshead speed of 5 mm/min. flexural testing was carried out according to ASTM D790 using three points bending method with the same testing machine for tensile testing at the same crosshead speed. Impact strength testing was done according to ASTM D256 by Izod impact machine. Hardness test was conducted using a Rockwell Hardness testing machine according to ASTM D785. All specimens were conditioned at a temperature of 23± 5°C and relative humidity of 50 ± 5 % for 2 days before testing. For each test, five replicate specimens were tested and the average values recorded.

III. RESULTS AND DISCUSSION

Tensile properties

The tensile properties of OPPF/epoxy biocomposites were probed to reveal the effects of the OPPF contents and its alkali treatment on the OPPF/epoxy interface and eventually on the tensile behaviour of the materials. Tensile strength and modulus of untreated oil palm press fibre (UOPPF) and alkali treated oil palm press fibre (AOPPF) reinforced epoxy composites were presented in Figures 1 and 2 respectively. Figure 1 shows that the tensile strength of the composites decreased with addition of 5 wt. % filler content and thereafter started to increase with increasing filler loading. The decrease may be linked to inadequate filler to reinforce the matrix of the composites. As the filler content increases from 5 - 20 wt. %, the tensile strength of the composites also increases but a decline in tensile strength was noticed beyond this point. Other previous results (Husseinsyah and Mustapha, 2011; Goud and Rao, 2011) show similar trend. The good tensile strength at low filler content may be attributed to good dispersion of OPPF in the epoxy resin, good wettability and good interfacial adhesion.

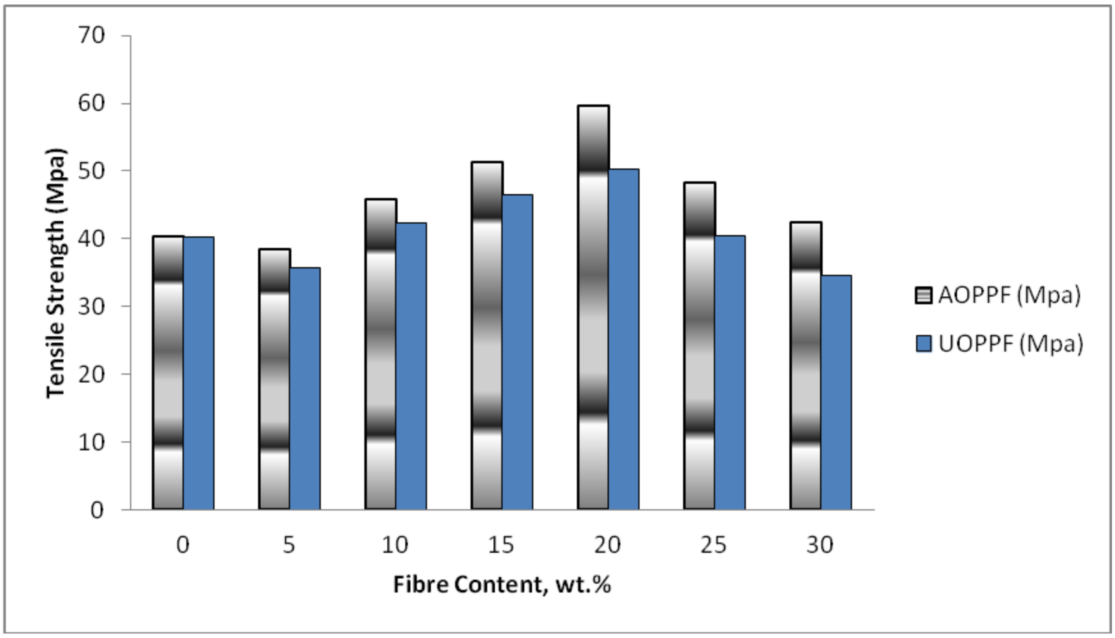

Fig. 1: Tensile Strength of untreated and treated OPPF/Epoxy composites

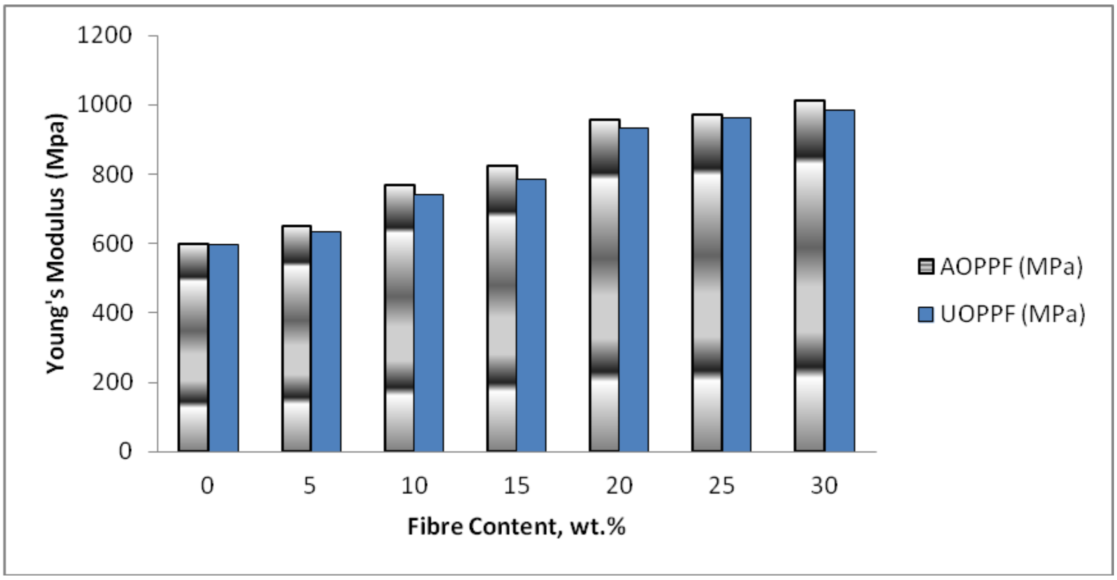

Fig. 2: Tensile Moduli of untreated and treated OPPF/Epoxy Composites

The decrease in strength after 20 wt. % content could be explained due to poor wettability, high porosity and voids resulting to a weak interface and inefficient stress transfer. It is worthy to note that all treated composites produced an improvement in tensile strength compared to untreated composites. An improvement of 7.97 % at 5wt. % of treated over untreated fibre whereas 18.79 % at 20 wt. % was also seen over untreated one.

This improvement may be linked to the enhancement in the adhesion between the fibre fibrillation, reduction in diameter, and increase in the number of reactive sites and changes in chemical compositions of the fibres when alkali treated. From fig. 2, it is evident that the incorporation of OPPF improved the tensile modulus of epoxy for both untreated and treated fibre composites and the values increase as the filler contents increase.

On comparison, alkali treated OPPF composites showed higher improvement when compared to untreated composites. Alkali treatment will remove some hemicelluloses, lignin, glue and other extractives in fibre bundles which yields higher percentage of α-(alpha), cellulose in natural fibres (Jayaramudu et al., 2009). This causes the fibre surface to be rough leading to improved interface between fibre and matrix. Alkalization causes fibre bundle breakages (fibrillation) into small fibres thereby increasing the effective surface area available for wetting by the matrix (Yan et al., 2000). This results to a better fibre/matrix interface due to the reduction in fibre diameter, increased fibre aspect ratio and rough surface topography hence improved mechanical properties. Similar to our findings were the works of (Goud and Rao, 2011; Mohanty et al., 2001; Prasad et al., 1983 and Corradini et al., 2006).

Flexural Properties

Flexural properties of untreated and treated composites at various fibre contents for flexural strength and flexural modulus are respectively presented in figures 3 and 4. As was observed in tensile strength, the flexural strength of OPPF/epoxy composite increased with increasing fibre content up to 20 wt. % but a gradual decrease in tensile strength was seen with higher fibre contents (Fig. 3).The reduction could be attributed to inadequate filling of epoxy resin into the OPPF during composite making which favoured fibre/fibre interaction than fibre/matrix interaction.

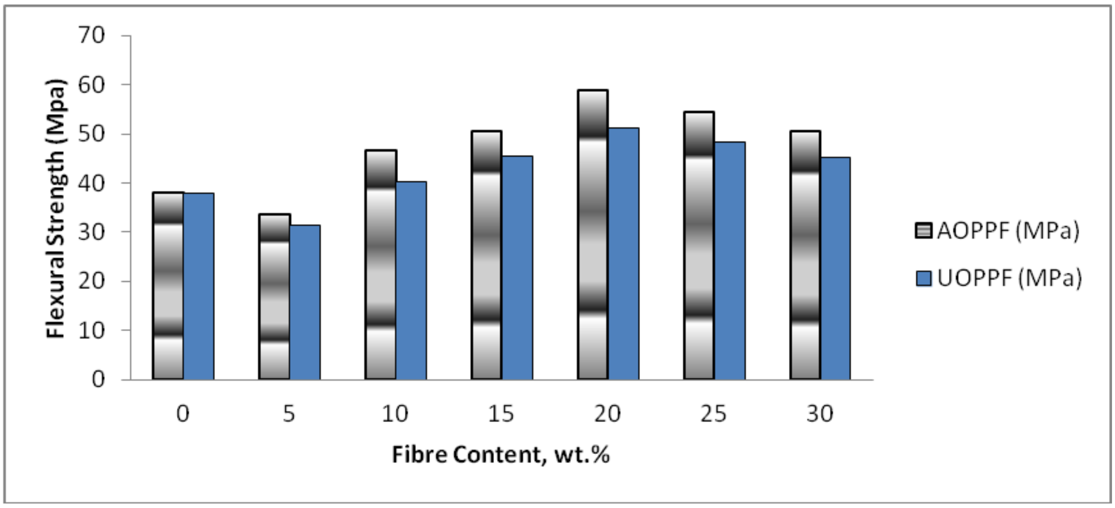

Fig. 3: Flexural Strengths of untreated and treated OPPF/Epoxy composites

Flexural modulus on the other hand increased linearly with increasing fibre content up to 30 wt. % investigated (Fig. 4). This behavior may be linked to the incorporation of rigid OPPF filler which offered a characteristic reduction in the ductility of epoxy resin matrix and hence resulted to the increase in flexural modulus. For alkali treated OPPF/epoxy composites, flexural properties are higher than those of untreated counterparts. This confirms the contributions of alkalization of fibres in terms of changes of fibre properties and fibre/matrix interface improvement. Alkali treated OPPF/epoxy composites at 20 wt. % showed 55.09 % improvement in flexural strength and 44.25 % in flexural modulus when compared with the neat resin. Alkali treatments of fibres cause fibrillation of fibres which increases the effective surface area available for contact with the matrix and hence improved interfacial adhesion. Therefore, modification of OPPF improved OPPF/epoxy biocomposite compatibility and bonding characteristics by producing compatible surface energies with developed interface bonds. Similar to our result were the works of CaO et al., (2005) and Bledzki and Gassan, (1999) on alkali pre-treatment of fibres.

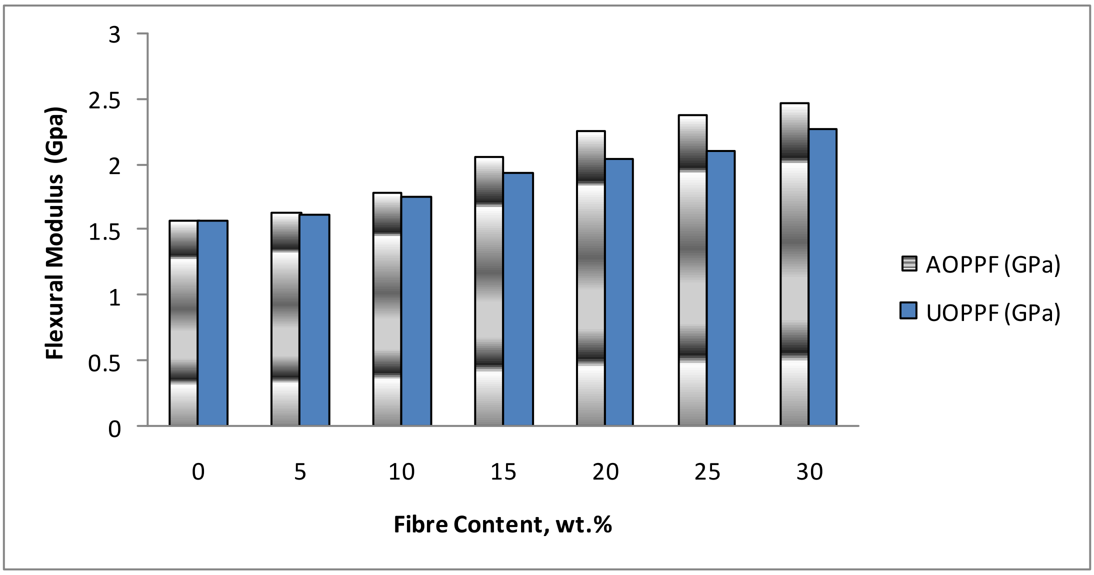

Fig. 4: Flexural Moduli of untreated and treated OPPF/Epoxy composites

Impact Strength

The impact properties of a composite material are directly related to its overall toughness. Composite fracture toughness is affected by inter laminar and interfacial strength parameter (Mishra et al., 2003). Figure 5 shows the effect of strength of untreated and treated OPPF/epoxy composite with variation in filler volume fractions. From the figure, it is clear that the impact strength increased steadily with increase in filler concentration for both untreated and treated composites showing 20.04 KJ/m^2 and 23.69KJ/m^2 with 20 wt. % filler content respectively. However, there is a decline in inpact strength on further increase in filler content which was found to be more prominent in untreated fibre than the untreated ones.

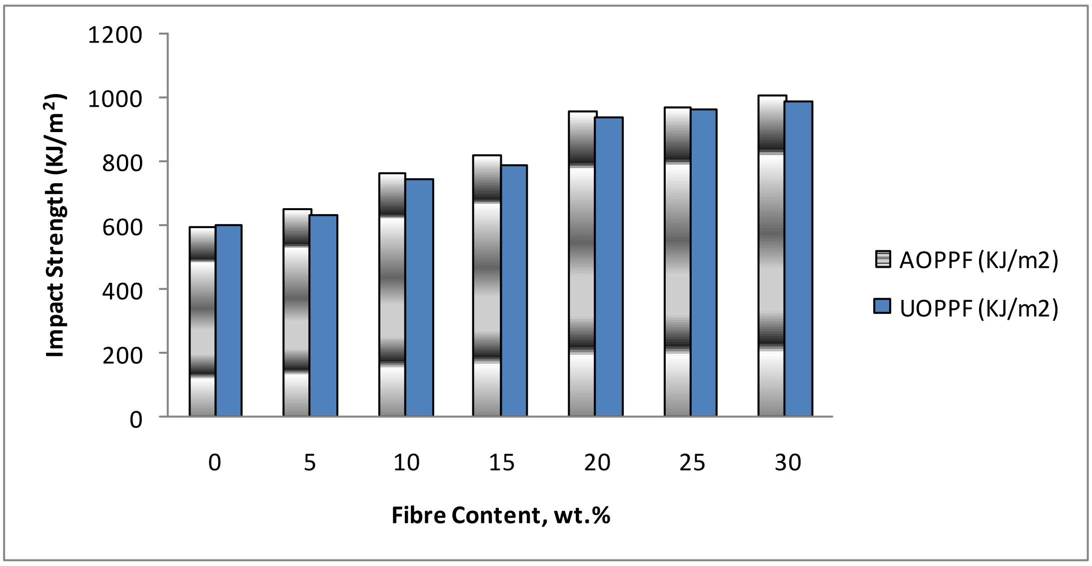

Fig. 5: Impact Strengths of untreated and treated OPPF/Epoxy composites

This may be assigned to the existence of weak interfacial interaction between the filler and matrix material for higher filler concentration beyond 20 wt. %. Bengtsson et al., (2007) reported that agro fibres act as stress concentrates in a polymer matrix thus reducing the crack initiation energy and consequently the impact strength of the composites. It has been reported that the impact strength of a composite is influenced by many factors including the matrix fracture, fibre/matrix debonding and fibre pull out (Zhong et al., (2007). Conversely, the treated OPPF/epoxy composites showed an improvement of the impact strength compared to the untreated OPPF/epoxy composites. The treatment of the OPPF improves the compatibility and promotes the ability to dissipate energy during fracture.

Hardness Properties

The variations of the hardness of composites as a function of fibre content are presented in Figure 6. In this study, hardness was a measure of resistance to indentation and the values got were used to estimate the mechanical strength of each composite. This shows that fibres that increase the modulus of composite are expected to increase the hardness of the composite because hardness is a function of the relative fibre volume and modulus.

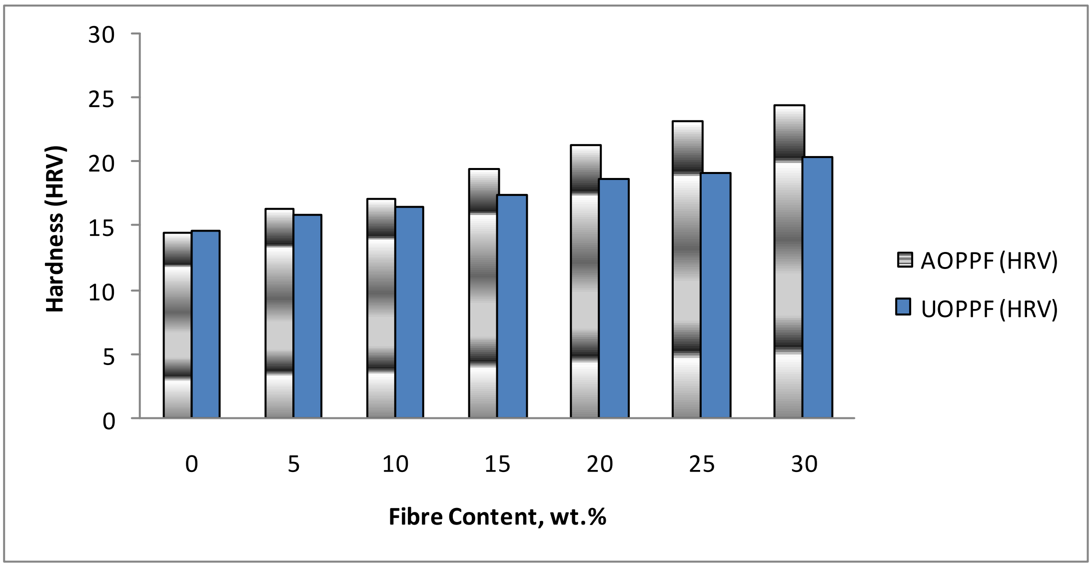

Fig. 6: Hardness properties of untreated and treated OPPF/Epoxy composites

The hardness of both untreated and treated OPPF/epoxy composites was found to increase progressively with increase in the fibre content. It is observed that the treated fibres showed better hardness properties than the untreated ones at all filler content investigated. The highest values of 20.306 HRV and 24.482 HRV at 30 wt. % filler content were obtained for untreated and treated composites respectively. This scenario could be linked to the better adhesion of the matrix to the fibre brought about by the fibre treatment with NaOH. Similar to our findings were the results of Idrus et al., (2011), Rahman et al., (2008) and Elvy et al., (1995). The addition of natural fibres to a polymer matrix has been seen to reduce flexibility of the resulting composite which in turn increases the stiffness. Rahman et al., (2010) reported that the hardness properties of a composite were enhanced as a result of the decrease of flexibility and increase of stiffness of a composite.

IV. CONCLUSION

Oil palm press fibre (OPPF) reinforced epoxy resin composites were prepared by varying fibre concentrations. The influence of alkali treatment of OPPF/epoxy composites on tensile, flexural, impact and hardness properties has been studied. Composites from treated OPP fibres had higher values of mechanical properties than those made from the untreated fibres. This is because the alkali treatment improves the interface adhesion characteristics of the fibre and matrix by removing hemicelluloses, lignin and other impurities from the fibres. In the present work, it is found that optimum values and significant improvements in tensile, flexural, and impact properties where at 20 wt. % filler content for treated composites. Generally, results indicated a better wettability of treated fibres with matrix, and corroborated the function of treated oil palm press fibre as not only filler but also as a reinforcing agent.

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