Effects of the chemical treatment of avocado pear wood filler on the properties of LDPE composites

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Article Information

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The characteristics of wood filler-thermoplastics composites coupled with the incessant order of these products on a daily basis have long been of scholarly interest. This work is aimed at investigating the influence of chemical-modified avocado pear wood filler (APWF) on the mechanical and water absorption behavior of low-density polyethylene (LDPE). The avocado pear wood filler-low density polyethylene (APWF/LDPE) composites were prepared by fresh APWF (UN) modified by the action of sodium hydroxide (NS), sodium hydroxide/acetic acid (AA) and sodium hydroxide/acetic acid/maleate polyethylene (MP), respectively and then merged with a low-density polyethylene (LDPE) matrix by injection molding, respectively. The effect of the filler content on the properties was evaluated. The active groups and morphology of APWF/LDPE composites were studied using a Fourier transform infrared (FTIR) spectrometer and a scanning electron microscope (SEM), respectively. The treated APWF exhibited better mechanical properties and higher water resistance than the UN with a greater improvement for the MP of the APWF/LDPE composite as captured by a FTIR and SEM graph. Consequently, the MP of an APWF/LDPE composite is highly recommended as an application for furniture and finishings.

The essence of using a woody-supplement in a composite preparation is targeted to enrich the physio-characteristics of a polymer matrix at a reduced cost [1]. The positive effect of natural filler-polymer-composites leads to a generation of new products [2].

APWF has reasonable physio-characterized values [3], which make it useful as a flammable agent for heating [4], forutensils and for the flat board process [5]. The growth of APWF production has risen 139 % in Nigeria [4]. If measures were taken for using avocado wood, the dependence on fossil fuel in the country would be reduced enslavement. APWF exhibits the improved properties of a high density polyethylene matrix but it is seldom used in other thermo-polymeric materials [6].

The superiority of lignocellulose-filler-polymer composites is proportional to the composition of the filler, the grain size, weight, surface modification and bonding strength of the polymer [7, 8]. Interest in these particulate composites for marketing purposes has increased, but the poor bond between the filler and the matrix, low thermal and water resistance is an issue that requires an adequate solution [9-11]. This irregularity is a factor in the intermolecular hydrogen bonding of the APWF [12, 13]. The only way to inhibit the possible shortcomings of the bonding force between lignocellulose additives and polymer matrix is by means of a chemical handling system [14, 15]. The major modification of powdered-wood which results in high quality composites includes acetic acid, maleate polyethylene, maleated polypropylene, sodium hydroxide etc, [16].

The past researchers have deliberated on the use of diverse types of wooden cellulosic extractions for making composite manufacturing products. For example: bamboo [14, 17, 18], acacia [19, 20] maple [21], white cedar and Jack pine [22], and paulownia [23]. But, these investigations involving treated APWF on LDPE composites have remained skeletal.

This present research is based on developing APWF/LDPE composites through various treatment processes, thus yielding a selection of composites with optimum applicability for household implementation. The effects of APWF on LDPE and post-treatment were exposed by FTIR and SEM.

Experimental procedure

APWF processing. The APWF (timber) was found in the southeastern region of Nigeria at the Enugu state metropolis. The timber was crushed and dried for 8 h over 14 days and ground at 150 μm screening.

Chemical treatment of APWF. The first stage of modification is the immersion of the APWF in 6 vol.-% aqueous NaOH of 98 % pure solution from Pvt. Limited, India, for 960 mins (NS). The second stage was accompanied by 4 vol.-% CH_3COOH through 60 minutes of soaking (AA). The CH_3COOH 98 % pure comes from BDH limited, England. The alkalization and acetylation steps for delignification were carried out by washing in distilled water, filtering and drying for 8 h, respectively. The acetylated APWF was added later along with MAPE (maleated polyethylene) 5 % by weight and homogeneously mixed (MP). The MAPE of 4,200 g × 10 min^{-1} and 190 °C × 2.16 kg^{-1} melting flow index and 0.905 g × cm^{-3} density was bought from the Sigma-Aldrich Chemical Corporation, USA.

APWF/LDPE composite preparation. The raw LDPE with amelt flow index of 0.33 g per 10 min was employed as the matrix for the composite and was purchased from the Exxon Mobile company, Suadi Arabia. Multiple concentrations of APWF at 5, 10, 15, 20, 25 and LDPE of 95, 90, 85, 80, 75 wt.-% were used to form the composites of APWF/LDPE, respectively. The injection molding composite manufacturing method was utilized to mold the composites.

Tensile, flexural, hardness testing. These analyses were executed using a universal tensometer BSS1610 model no 8889 from England. The calculations of the tensile strength, elongation, flexural strength and modulus, hardness were performed using Equations (1), (2), (3), (4) and (5), respectively. The evaluation of elastic modulus was determined by applying the linear-tangent of stress-strain graph [24].

$$U = F_{Max}/A \tag{1}$$

$$E = \frac{\Delta L}{L} \times \frac{100}{1} \tag{2}$$

$$F_S = 1.5\ QL_s/wv^2 \tag{3}$$

$$M_E = L_s^2 \frac{G}{2wv^2} \tag{4}$$

The indentation of the proportional height for the sample was measured. The hardness was calculated using Equation (5).

$$B_{HN} = \frac{2P}{\pi DD - \sqrt{D^2 - h^2}} \tag{5}$$

with U: tensile strength, F_s: flexural strength, F_{Max}: utmost tensile force, ΔL: length change, L: sample length, E: elongation, A: cross-sectional area, Q: applied force, L_s: flexural length, w: width, v: thickness, M_E: flexural modulus, G: slope of the force-deflection plot, B_{HN}: Brinell's hardness, D: bulb diameter and P: indentation load.

Impact testing. The sample was studied using a simple Charpy impact tester (Losenhausenwerk Düsseldorfer Maschinenbau AG. Düsseldorf, model 17562/1963, Germany). The impact sample was banged at the centre of a pendulum, and the approximated impact strength was computed.

Water absorption test. The water absorption test was obtained by the following method [25-28]. The APWF/LDPE composite was kept in an oven at 50 °C for 1800 s and weighed (W_1). It was immersed in water at a later point for 2016 h after the exclusion of water droplets on the surface using filter paper, the weight being recorded as (W_2). Water absorption was estimated using Equation (6)

$$m_w = \frac{W_2 - W_1}{W_1} \times \frac{100}{1} \tag{6}$$

with m_w: water absorption, W_1: original mass and W_2: final mass after dipping in water.

Fourier transform infrared (FTIR) spectrometry. An FTIR spectrometer model 8400S was used. The mixture of 50 mg KCl and 1.5 mg of APWF-LDPE was pulverized. The blend (KCl and APWF-LDPE) was passed into the (FTIR) device to determine the spectra.

Scanning electron microscopy. The SEM used was a Phenom ProX model at a capacity of 15 KeV. 1 g of powdered APWF/LDPE was slotted into the machine. After 5 s, a micrograph (SEM) was produced.

Results and Discussion

Mechanical and water absorption properties of APWF/LDPE composite. The effect of treated (NS, AA, MP) and untreated (UN) APWF on the tensile strength of APWF/LDPE composite is presented in Figure 1a. It can be observed that the tensile strength of the composite decreases from 9.75 to 6.8 MPa with an increase in UN loading as compared with the tensile strength of the pure LDPE matrix. This may be ascribed to an increase in the interfacial area between the APWF and the LDPE phase. This reduces the intermolecular bond in the matrix [19, 29]. The increase in tensile strength of the APWF/LDPE composite was surveyed for APWF treated AA and the NS of the APWF at 5 wt.-% loading. Nevertheless, a further increase in APWF minimized the tensile strength of the APWF/LDPE composite. This is due to void development and reduced wettability of the APWF in the LDPE matrix. This phenomenon was mentioned by a previous researcher [30]. The addition of MP to the LDPE swells the tensile strength of the APWF/LDPE composite to a peak of 15.92 MPa, an improvement over pure LDPE of 36.07 wt.-% at 20 wt.-%, and lowering the APWF content to 25 wt.-%. This elevation in tensile strength after the inclusion of AA, NS, and MP in the APWF/LDPE composite may be connected to the elimination of amorphous components and the influence of hydrophilic hydroxyl groups from the APWF [31, 29]. The MP yielded the best reinforcement for the LDPE.

Figure 1b shows the effect of filler loading on the elongation of an LDPE /APWF composite. By adding UN, AA, NS and MP to the APWF in the LDPE, the elongation of APWF/LDPE composite is lowered from 7.26, 6.1, 5.99 and 5.61 % to 6.12, 5.22, 5.31 and 4.88 %, respectively. This is discussed by Supri and Lim [32]. This may be ascribed to a weak stress transfer between APWF and the LDPE matrix as explained by various researchers [33, 34, 29].

The addition of APWF loading from 5 to 25 wt.-% for UN, AA, NS and MP in the LDPE leads to a drastic enhancement of the tensile modulus for the APWF/LDPE composite as seen in Figure 1c. The elastic modulus of 0.16 GPa was obtained for the pure LDPE matrix. The Young's modulus of the APWF/LDPE composite for UN, AA, NS and MP in LDPE is increased from 0.521, 0.643, 0.719 and 0.755 GPa to a peak level of 0.616, 0.751, 0.837 and 0.867 GPa at 0 to 25 wt.-% APWF content, respectively. The modulus of the APWF/LDPE composite for UN reaches an apex level of 375 % greater than pure LDPE. It can be concluded that MP exhibited the highest advancement in the tensile modulus of the composite over that of UN by 40.75 %, followed by NS with 35.88 % and AA being the lowest. This phenomenon depunds on the assumptin that by adding APWF to LDPE, spaces develop. These voids trim the ductility of LDPE, thus augmenting the stiffness of the composite [26, 32, 35-37].

Figure 1d shows the effect of filler loading on the flexural strength of the APWF/LDPE composite. During the increase in APWF from 5 to 25 wt.-%, the flexural strength of the composite for UN, AA, NS and MP marginally went up. This trend is due to the superior cellulosic strength which improves the interfacial bond of the APWF and the LDPE matrix through APWF

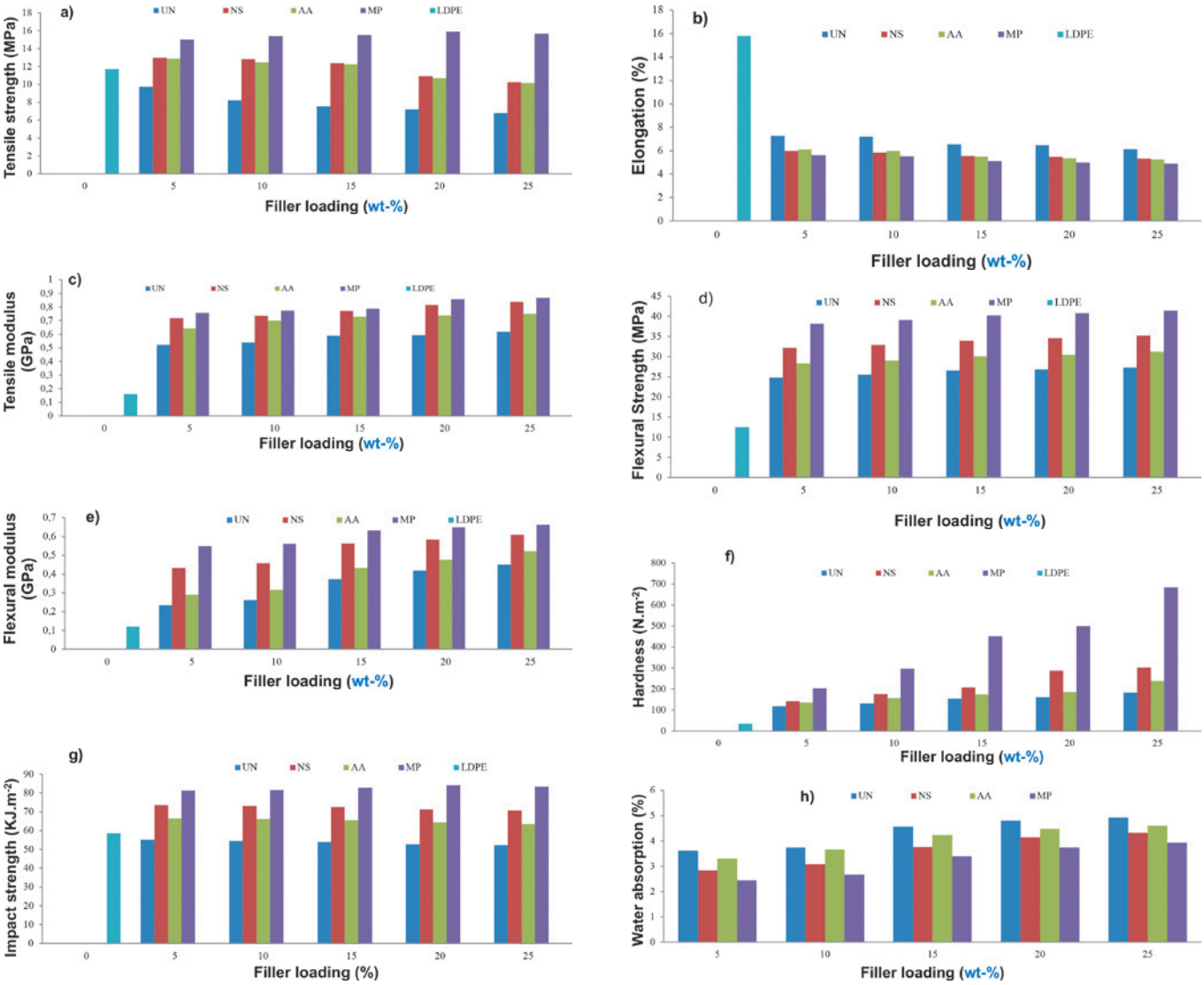

Figure 1: Effect of filler loading on various properties of the APWF/LDPE composite, a) tensile strength, b) elongation, c) tensile modulus, d) flexural strength, e) flexural modulus, f) hardness, g) impact strength, h) water absorption

modification. This phenomenon has been explained by earlier researchers [30, 38-40]. At 25 wt.-% APWF loading, the flexural strength of APWF/LDPE composite for UN increased to 27.27 MPa, an improvement over pure LDPE by 118.16 % with MP being higher than UN by 51.78 %.

Furthermore, as APWF loading is proportionately added from 5 to 25 wt.-%, the flexural modulus for APWF/LDPE composite, as illustrated in Figure 1e, improves. It can be seen that the addition of AA, NS, and MP to the matrix enhanced the flexural modulus of the composite. The ultimate flexural modulus was obtained by a filler loading of 25 wt.-% for the UN, AA, NS and MP of the APWF/LDPE composite. The bending modulus of the APWF/LDPE composite at UN is higher than that of the uncontaminated LDPE matrix by 275.83 %, while the MP exceeds the UN by 46.79 %. The occurrence is due to the greater compatibility of the APWF and LDPE as stated by more recent researchers [38-40].

Figure 1f shows the effect of filler loading on the hardness of the APWF/LDPE composite. The best hardness value was obtained by adding UN, AA, NS, and MP in APWF/LDPE composites at a filler loading of 25 wt.-%. The resistance to indentation by the addition of APWF to the LDPE leads to an upgrading of the bonding strength between the APWF and the LDPE matrix. The addition of APWF with AA, NS, and MP improved the hardness of the composite by 29.51, 64.49 and 273.22 %, respectively. The MP of APWF/LDPE composite is the effective modified process in terms of Brinell hardness. This trend has been described by various research projects in this field [38-40].

Figure 1 g depicts the significance of filler loading on the impact strength of the LDPE/APWF composite. The impact strength of the composite for AA and NS dropped from 0 to 25 wt.-% at its APWF weight. This can be attributed to an insufficient bond at the interphase of the APWF and the LDPE matrix [16]. Conversely, the impact strength of the APWF/LDPE composite for MP modification reaches a critical value of 83.33 kJ × m^{-2} and 81.25 kJ × m^{-2} at an increase of 20 wt.-% and 5 wt.-% load, respectively. This is a result of the increase in toughness of the composite [17, 37, 41, 42].

The influence of filler loading on the water absorption of APWF/LDPE composite for UN and treated APWF (NS, AA, and MP) at 12 weeks is shown in Figure 1h. The sorption resistance for the addition of APWF in LDPE at NS, AA, and MP increases

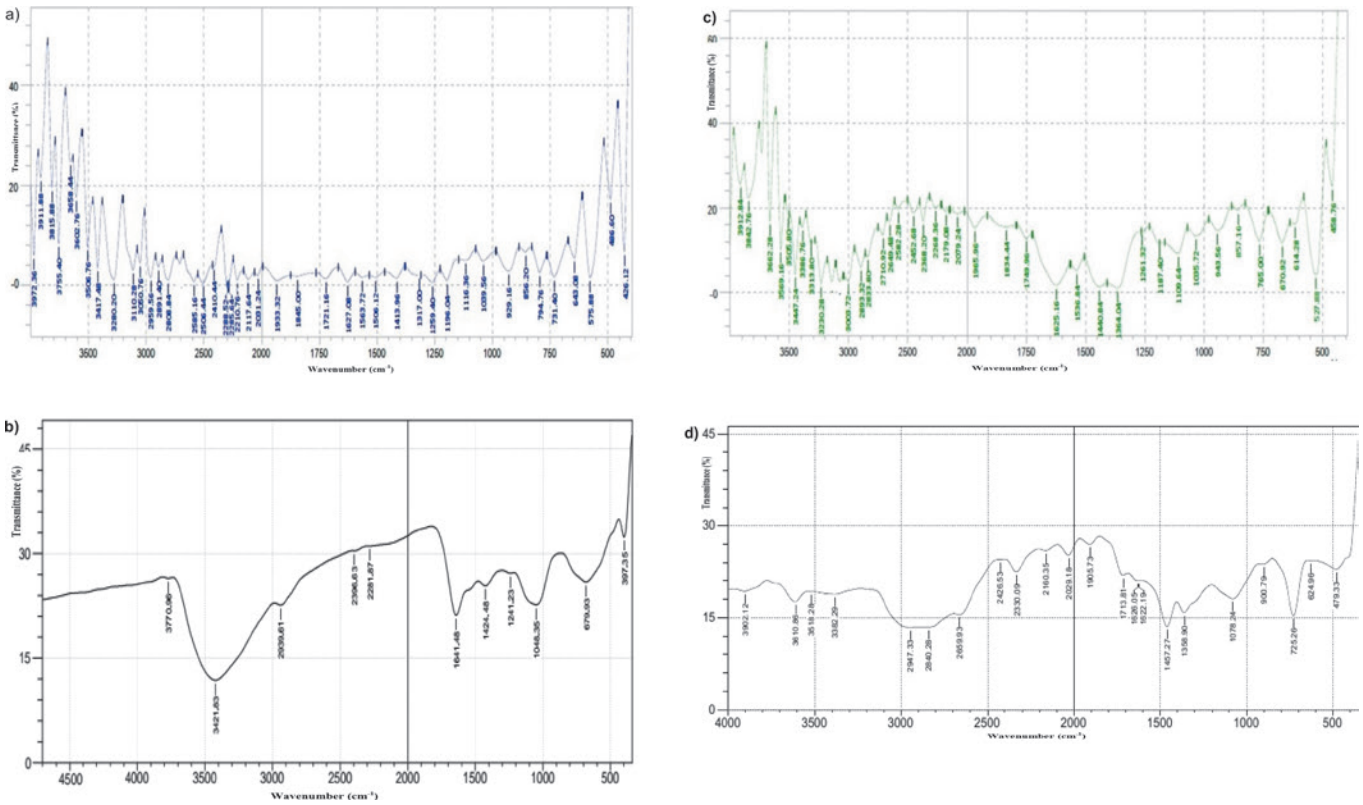

Figure 2: FTIR spectra of the APWF/LDPE composite at 25 wt.-% and APWF loading for a) UN, b) NS, c) AA, d) MP

while the UN is barely affected. The hydrophilic nature of the APWF in the composite causes water absorption for AA, and NS of the APWF/LDPE composite, respectively. This is described by Netra et al. [14]. The water absorption of the APWF/LDPE composite for MP was lower than that of UN, AA and NS when a variety of APWF values were injected. Modified APWF with the aid of chemical agents has shown a significant increase with respect to adhesion in the LDPE matrix. For this reason, the water dissemination rate in the APWF/LDPE composite shrinks. This has been described in various papers [26, 32, 43-45].

FTIR analysis of APWF/LDPE composite. Figure 2a-d shows the FTIR spectra of APWF/LDPE composites for UN, NS, AA, and MP, respectively. The FTIR values were extracted from the catalog [46]. Figure 2a shows the FTIR spectrum of APWF/LDPE for a composite with UN. The O-H group present in the APWF/LDPE composite displayed peaks at 3602.76 to 3280.20 cm^{-1}. However, absorption peaks and transmittance were adjusted by the insertion of NS, AA, and MP. The presence of carboxylic acid can be seen as being between 3110.28 cm^{-1} and 2506.44 cm^{-1} with a displacement of the absorption peaks. The region of 2401.44 to 2117.64 cm^{-1} was analyzed as containing phosphorus acid and ester compounds. The presence of polyamide at 2031.24 cm^{-1} is an indication of N-H and O-H functional groups in the APWF/LDPE composite. The absorption peak of 1713.8 cm^{-1} confirmed the presence of benzene ring aromatic compounds. Alkenes with C = H group corroborated with a peak of 1622.19 cm^{-1}. Aromatic nitro compound of NO_2 asymmetric stretching is peak at 1563.72 cm^{-1} and 1506.12 cm^{-1} (see Figures 2b and 2d). The wavelength at 1424.48 cm^{-1} and 1413.96 cm^{-1} registered N = N bond of an azo compound, respectively. The region of the wavelength at 1364.04 to 1317.0 cm^{-1} correspond as aromatic nitro-compound of NO_2 symmetrical was invisible in Figure 2b. The acryl group in cellulose, characterized in Figure 2d with a peak of 1261.32 to 1241.23 cm^{-1}, disappeared. The peaks at 1116.36 to 1035.72 cm^{-1} exposed the carbonyl groups (C-O) of esters compounds in the ccomposite. The crests of 943.56 to 614.28 cm^{-1} signifies the C-H out-of-plane bending of the alkenes. The C-Cl stretching of alkyl halide was found to characterize by absorption peaks from 575.88 cm^{-1} to 426.12 cm^{-1}.

There was a dislodgment of transmittance at the peaks of the carbonyl groups [14, 42, 47] when the APWF was modified by NS, AA and MP in the LDPE, as seen in Figures 2a to 2d, respectively. The changes in the peaks is evidence of an improvement in the properties of the composite due to treatment.

SEM of the composites. The morphology of UN, NS, AA, and MP in APWF/LDPE composite is expressed in Figure 3a to 3d, respectively. Figure 3a reveals the appearance of APWF particles and cracks on the surface of the composite. In Figure 3b, the departure of some fractures can be observed. This might be responsible for degration of redundant components in APWF and improve the bond between the APWF and LDPE. The defect which is an attribution of better dispersion of APWF is lower in Figure 3c than that in Figure 3a . This explains the upgrade in the interfacial attachment linking the APWF and the matrix [48-51]. Figure 3d reveals fewer cracks than in Figure 3a to 3c. Thus, there is an improved surface contact and bond strength between the APWF and LDPE with MP as compared with that of AA and NS.

Conclusions

APWF has been seen to be comparable to previous cellulosic material in its use as a composite. The exploit of NaOH, NaOH/

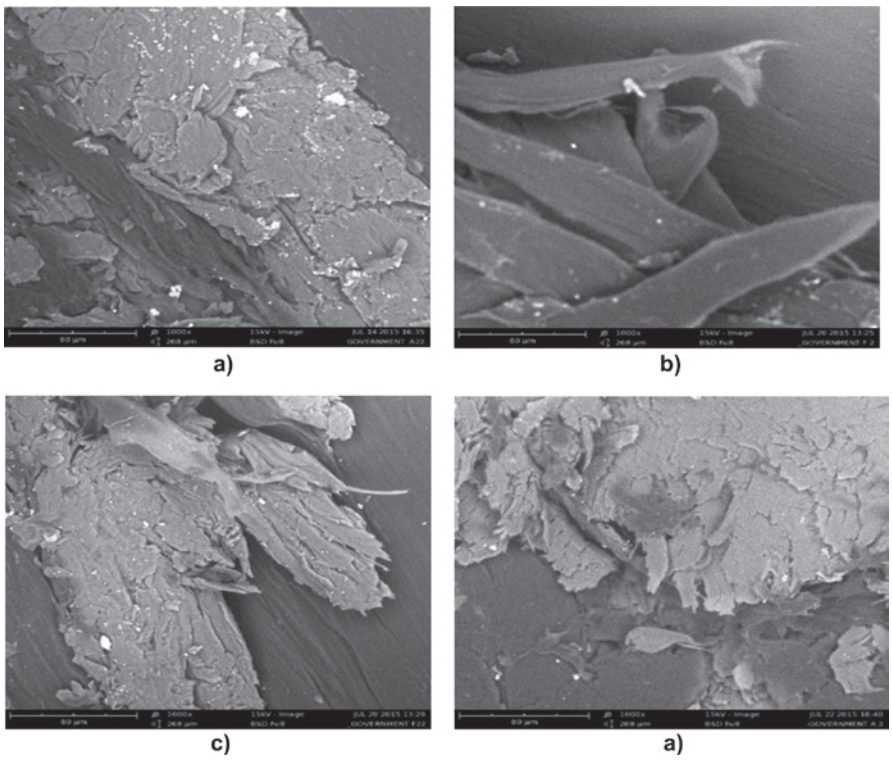

Figure 3: SEM picture of APWF/LDPE composite at 25 wt.-% and APWF loading for a) UN, b) NS, c) AA, d) MP

CH_3COOH, NaOH/CH_3COOH/MAPE of avocado pear wood improved the mechanical properties and water absorption resistance of the composite. Thus, the amalgamation of three chemical reagents for APWF treatment demonstrated the best modification method for an APWF/LDPE composite for indoor use due to the improved characteristics of the end-products.

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