



Modification of Shea Butter Wood Fiber for Fiber-Polymer Composites in Automotive Interior Cabinets

Government Rabboni Mike¹, Odiakaose Chili², James Nigibonsogiftson³

Abstract

The limitations of renewable material obtain from agro-based in the manufacturing sectors indicates much prospect to substitute synthetic fibers and non-metal compounds which are the traditional materials employ at esteem years old. The request of novel organic fiber, that are price friendly, minimal-mass-volume ratio and commonly available, that is reason shea butter wood flour (SBWF) employs in this work and competes with existing fibers for alternative innovative material to solve mankind issues. This research involved determination for the composition of crude and pre-treated SBWF. The SBWF was crushed and powered. The SBWF was sieved to a specific size. The SBWF was processed under controlled parameters: concentration of NaOH from 5, 10, 15 %w/v and immersed time 2, 4, 6 hr. Before modification, the crude compositional constituent of the SBWF was obtained based on cellulose (CLC), lignin (LGC) and hemicelluloses (HMC). Then, the SBWF was pretreated at the variant concentration ant soaking period. The chemically compositions of the chemically modified SBWF was obtained and tabulated. The Fourier transform infra red (FTIR) and scanning electron microscopy (SEM) to examine the active radicals and morphology were imposed on the crude and pre-treated SBWF at ultimate condition. From the displayed outcome, the raw compositional constituents were 48.5 %, 13.27 % and 24.76 % for CLC, LGC and HMC, respectively. On the other note, the pre-treated SBWF showed a significant improvement in CLC, LGC and HMC at the variation of concentration and time. The FTIR and SEM examination showed displacement in the position of apex for the spectrum and more roughness of the micrograph due to the aid of chemical influence of the SBWF, respectively. Finally. at optimum state of 10 % w/v NaOH and 4hr immersion period, the CLC, LGC and HMC were 75.15 %, 10.28 and 4.97 %, respectively. The result exhibited by CLC from the novel SBWF is a promising engineering component for automobile parts.

✉ Government Rabboni Mike: govt_4real@yahoo.com; Phone number: 07048059184

¹Faculty of Engineering, Department of Chemical Engineering, Federal University Wukari, Taraba State.

² Faculty of Engineering, Department of Mechanical Engineering, Federal University Wukari, Taraba State.

³Faculty of Pure and Applied Sciences, ³Department of Industrial Chemistry, Federal University Wukari, Taraba State.

Keywords: Shear butter wood fiber; NaOH pre-treated; Compositional constituent; cellulose; lignin; hemicelluloses; FTIR; SEM

Article history

Received: July 25, 2025

Received in revised form: September 23, 2025

Accepted for publication: September 25, 2025

Available online: September 29, 2025

1.0 Introduction

Non-metallic substances as such as Na_2CO_3 , CaCO_3 , MgO , etc., were formerly used material for composite production, however, the use of these inorganic materials are very cost effective, and this led to a need to source out a cheap material from agro-plant to minimize the cost of inorganic material in composite production (Weyenberg *et al.*, 2006; Government *et al.*, 2017; Government *et al.*, 2018). Generally, composite is the combination of two/ more components with separate individual characteristics to yield a single compound/mixture with qualities varies from each of component substances (Wong *et al.*, 2010; Atuanya *et al.*, 2014; Government & Onukwuli, 2025). It has large parts of it taking as matrix which can be polymer/ceramics/metals while the other constituents found in minute form which might be fiber which is either natural fiber/non-metals/ and coupling agents (Wong *et al.*, 2010 Government & Onukwuli 2025). It has the following distinguished properties (Government *et al.*, 2019; Government *et al.*, 2020a & b); Okeke *et al.*, 2023): it is lighter in weight, as result of this merit, it is applicable for automotive parts in fuel energy conservation, and saves the cost of materials. These also improve the specific strength, elastics stiffness, flexural strength, modulus, hardness and impact energy, etc. It can be utilized in many areas of work such as aerospace, building, electronic components, boats, railway coaches, etc. This material also acts as a perfect replacement for metals or alloys in manufacturing sector and generates urge amount money in terms material rice (Wong *et al.*, 2010; Obasi, 2015; Government & Onukwuli, 2025).

In this current era, plant cellulosic substances have been the main raw materials in the emerging industry for novel fiber-plastic composites (Obasi, 2015). The major productions which these can serve as purely substitute are phone casing, automobile components, door panel, containers and packaging material, etc. These agro-based fibers have totally replaced non-metals from the soil and rocks for finished products. Agro-based plant yields major constituent which defines as CLC that provide strength support to the plant-polymer composite (Bogoeva-Gaceva *et al.*, 2007; Netral *et al.*, 2012; Wang *et al.*, 2016; Srinivas *et al.*, 2017). Numerous research have shown that plant-dependent-fiber with large quantify CLC is essential for fiber-polymeric composite (Bogoeva-Gaceva *et al.*, 2007; Netral *et al.*, 2012; Dungani *et al.*, 2016; Government *et al.*, 2017; Government *et al.*, 2018), most importantly, lignin and hemicellulose face reduction to keep away from the issues of incompatibility when fully utilized for commercialization (Wu *et al.*, 2000; Rowell *et al.*, 2000; Nachtigall *et al.*, 2007; Setswale *et al.*, 2017). The challenge of compatibility is quite pertinent and needs to be resolved for avoidance of the final end product to experience water absorption with time (Haristov & Vasileva, 2003; Sari *et al.*, 2017).

Today, industrialists have emphasized on the substitution of synthetic fiber to organic fiber as a result of their uncommon characteristics such as insulating capacity, light weight, heat resistance, modulus, biodegradable and cost. Due to these qualities, manufacturers have also informed researchers over the world to beef up

studies for this area of research for generation of billions of dollars to them (Jawaid and Khalil 2011; Marwan & Nasim, 2016; Muryanto *et al.*, 2015).

Cellulose generates the apex components of agro-based-plant substance with hemicelluloses and lignin in correspondence, respectively (Netral *et al.*, 2012; Dungani *et al.*, 2016; Shuhaida and Soh, 2016). The power of cellulosic material is proportional to the characteristics of the composite material when used its constituent (Bogoeva-Gaceva *et al.*, 2007; Netral *et al.*, 2012; Suryanto *et al.*, 2013). Research has confirmed that cellulosic component enhances high strength of polymer composite (Bogoeva-Gaceva *et al.*, 2007; Netral *et al.*, 2012; Dungani *et al.*, 2015; Government *et al.*, 2017; Government *et al.*, 2018). Modification of plant - based fiber is predominantly to cut out weaken gummy constituents from the fiber which include lignin, hemicellulose and other compound that is connected the fiber (Wu *et al.*, 2000; Rowell 1998; Nachtigall *et al.*, 2007; Johar *et al.*, 2012). This invariably resists the influence of incompatibility and water absorption for utilization of domestic and industrial needs of the composite time (Haristov and Vasileva, 2003; Government *et al.*, 2017; Government *et al.*, 2018).

In this day and age, scholarly researches (Valadez-Gonzalez *et al.*, 1999; Ray *et al.*, 2002; Herrera-Franco and Valadez-Gonzalez 2005; Wong *et al.*, 2010) have proven that lignocellulose compounds acknowledge chemical variation of lignin and a cellulosic fiber boosts their collaboration with polymeric arrangements. Multiple fibers previously employed after pre-treatment for mass production to solve engineering problems, such as pinewood (Chen *et al.*, 2014), rice straw (Shuhaida & Soh 2016), waste betel nut (Lazim *et al.*, 2014), century fiber (Reddy *et al.*, 2013) sugarcane base (Ahmadi *et al.*, 2016). However,

SBWF has not been systematically studied for automotive composites, due to its scarcity in scientific literal work.

In this study, a novel SBWF, which is low-cost, biodegradable, and widely available, was chemically modified using NaOH, with consideration given to treatment time and concentration. The FTIR and SEM analysis were investigated on the pure and purified SBWF at ultimate condition. This is to ascertain its cellulosic constituent for its accessibility for composite production in automobile interior.

2.0 Materials and Methods

2.1 Materials

Material collection

The SBWF was derived from Wapan Nghaku in Wukari Local Government Area of Taraba State. The SBWF was washed with de-ionized H₂O, sun dried for 11 days at 8 hr before crushing and sieved using 12 mesh (1700µm) sieve size. The SBWF fine grain was stored in a sealed container at room temperature.

2.2 Methods

Pre-treatment process of SBWF

15 g of the crushed and sieved SBWF was soaked in NaOH solution with concentration of the alkali varied from 5-15 %w/v. The solid part of the SBWF was washed at pH 7. The time of soaking was also varied from 2-6 hr after which CLC, HMC, and LGC were examined, respectively.

Determination of CLC and LGC

The crude and chemically prepared SBWF were analyzed for its component's constituent at varying concentrations and time utilizing the Chesson's method (Mahyati *et al.*, 2013; Agu *et al.*, 2014; Government *et al.*, 2019; Government *et al.*, 2020 a, b; Okeke *et al.*, 2023) with the procedures:

(K) 1g of SBWF and 150 ml distilled H₂O was warm to attain at 100°C for 1hour and the weight recorded.

(L) The mixture (SBWF at 150 ml of distillation H₂O) was dried, filtered, and weighed until the weight was constant.

(M) The ruminant in B was mixed with 150 ml of 0.5 M H₂SO₄ was passed through heating for 100 °C at 1hr. The fusion was filtered, dried and weighed till reading is fixed

(N) The residue was mixed with 10 ml of 72 %w/v H₂SO₄ to maintain normal temperature for 4 hr and then subject to heating for 1 hr and weighed.

(O) The final remains were further subjected to heat until it turned to ash and weighed. The CLC and LGC were estimated as viewed in Eq. 1 and Eq. 2, respectively.

$$\text{CLC}(\%) = \frac{(M-N)}{K} \times 100 \quad (1)$$

$$\text{LGC}(\%) = \frac{(N-O)}{K} \times 100 \quad (2)$$

Determination of HMC

2 g of the SBWF deposit was injected in the beaker and 10 ml aqueous NaOH was discharged in the containing material. The mixing was maintained at a vibration of 300rpm with the aid of orbital shaker with the alkali solution. The alkaline solution was field frequently to maintain at 20°C. Distilled H₂O of 33 ml was introduced in the container and placed at 1 hr. The weight of the ruminant after the process was evaluated as (L), The remains in A was move into a crucible where 100ml NaOH was introduced again followed by 200ml distilled H₂O, and 15ml CH₃COOH. The total mixture was finally dehydrated to the weight (L) to determine the SBWF HMC employing Eq. 3. The cubicle with the residue was dried and weighed (L), the HMC of SBWF was computed using Eq. (3).

$$\text{HMC}(\%) = \frac{\text{residue weight (K)} - \text{residual weight in cubicle (L)}}{\text{residue weight (K)}} \quad (3)$$

FTIR Investigation

The virgin and the alkalized SBWF with the best components composition were examined by

Shimadu 8400s FTIR facility. The specimen to be injected into this facility involved combination of 50mg of KBr + 1.5mg NLWBF. The combined compound was pulverized, passed into a die for formulation of pellet which was moved into the machine for scrutinization to obtain the FTIR spectrum. The equipment has TGS detector, placed in a frequency of 0.1 cm⁻¹ and the spectra were measured at 4 cm⁻¹ precision varied from 800 to 3500 cm⁻¹.

SEM examination

1 g of crude and alkali-purified in each specimen was ground and transferred in the SEM equipment. After a period of 5 s, the micrograph was generated. The model employed was Phenon ProX with energy of 15 KeV.

3.0 Result and Discussion

The characteristic components of SBWF as captured in Table 1. It was noticed that the CLC content for crude SBWF was 48.50 %. The CLC of SBWF was proportional to that of kenaf (45-57 %) (Taj *et al.*, 2007; Agu *et al.*, 2014), oil-palm (44.20-49.60 %) (Abdul-khalil *et al.*, 2006; Dungani *et al.*, 2016) as stated by previous study. Also, the SBWF HMC content was observed to be 13.27 %. SBWF HMC showed close connection with that of jute (12.55-13.65) (Mwaikambo *et al.*, 2002; Dungani *et al.*, 2016), and ramie fiber (13-16 %) (Hattallia *et al.*, 2002; Wambua *et al.*, 2003; Hoareau, 2004). Furthermore, the SBWF LGC content was observed to be 24.76 %. This is also similar to other obtainable fiber such as bamboo fiber (21-31%) (Hattallia *et al.*, 2002; Hoareau, 2004), sugarcane (24.35-26.30%) (Wambua *et al.*, 2003; William & Patrick 2017, Hemmasi *et al.*, 2001; Dungani *et al.*, 2016), oil-palm (Abdul-khalil *et al.*, 2006; Dungani *et al.*, 2016). In the view of the fact that the composition of SBWF demonstrated parallel properties with that of other accessible natural fiber; SBWF is proposed for automotive parts etc. (Dungani *et al.*, 2016; Agu *et al.*, 2014).

Table 1: Individual components of raw SBWF

Wood Fiber	CLC (%)	HMC (%)	LGC (%)
SBWF	48.5	13.27	24.76

The consequence of NaOH on the CLC of SBWF is described in Figure 1. It was observed that as the NaOH concentration increased from 0 to 15% w/v, the CLC of SBWF was enhanced from 48.5 to 78.43 % at soaking time of 2 hr. The percentage increase between the unrefined and the refined SBWF at these variant concentrations was found to be 29.93 % at this resident time. This trend occurs during immersion of SBWF in alkali solution, the bonds that hold the constituent of the fiber were broken. This allows some of the unneeded component to remove from SBWF as an impurity in the immersion solution (Oushabi *et al.*, 2017). Also, when the resident time for the absorption of SBWF further increases from 4hr and 6hr, the CLC of the fiber improves when compared than the purified fiber from 48.5 to 72.58 % and 48.5 to 65.62 %, respectively. Furthermore, as the absorption time of SBWF in NaOH solution increase, the CLC reduces.

Notwithstanding, at 4 hr of soaking, the CLC increases from 70.68 to 73.58 % and decreases from 75.15 to 73.58 % when the concentration increases from 5 to 10 % and reduction can be seen from 10 to 15 % increase of NaOH concentration in SBWF absorption solution. Similar observation was recorded at 6 hr soaking time with total reduction of the cellulose from 67.74 to 65.62 %. The occurrence as a result of at higher concentration of NaOH increment in SBWF immersion, part of the cellulosic composition of the fiber has been annihilated (Oushabi *et al.*, 2017; Palamae *et al.*, 2017). However, the optimum CLC was viewed at 75.15 % which corresponds at the concentration of NaOH 10 % wt. and treatment time of 4hr. it can be concluded that, any further increment in concentration of NaOH than this concentration, will lead to reduction of the CLC of SBWF than this concentration and time. This analysis studied toe the trend of earlier works (Government *et al.*, 2019; Oushabi *et al.*, 2017; Palamae *et al.*, 2017; Shuhaida & Soh 2016; Barlianti *et al.*, 2015).

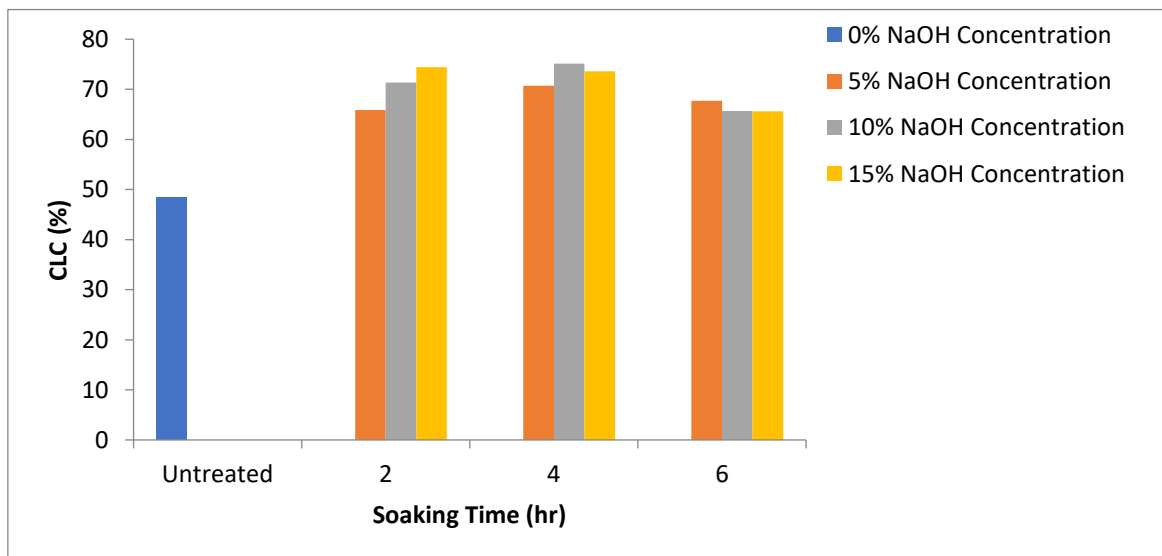


Figure 1: Influence of NaOH pre-treated variables on the CLC of SBWF

Figure 2 illustrates the effect of treatment parameter on the HMC of SBWF. From Figure 2, a noticeable removal of the HMC of SBWF was felt when the concentration of SBWF

improves from 0 to 15 %. At this state, the HMC was reduced from 13.27 % to 5.26 % at a constant time of 2 hr. The efficiency of the SBWF HMC reduction between the crude and

the pre-treated fiber was found to be 60.36%. This may be attributed after modification of SBWF in the solution of NaOH, the extractive and other additional components including the HMC has been removed to the solution of soaking. In this process, the SBWF has been fully activated by hydroxyl group that led to the introduction of alkoxide in composition of the fiber (Oushabi *et al.*, 2017; Palamae *et al.*, 2017). Similar observation was recorded at 4hr and 5hr when the immersion time increases. For

4hr and 5hr, the percentage removal between the unmodified and chemically modified SBWF was discovered to be 50.94 and 31.42 %, respectively. In conclusion, it can be stated that the percentage removal of HMC increases at the absorption time of soaking; this is as a result of too much soaking time reduces the HMC removal of SBWF. Scholarly studies have displayed similar trend (Government *et al.*, 2019; Oushabi *et al.*, 2017; Palamae *et al.*, 2017; Shuhaida and Soh 2016; Barlianti, *et al.*, 2015).

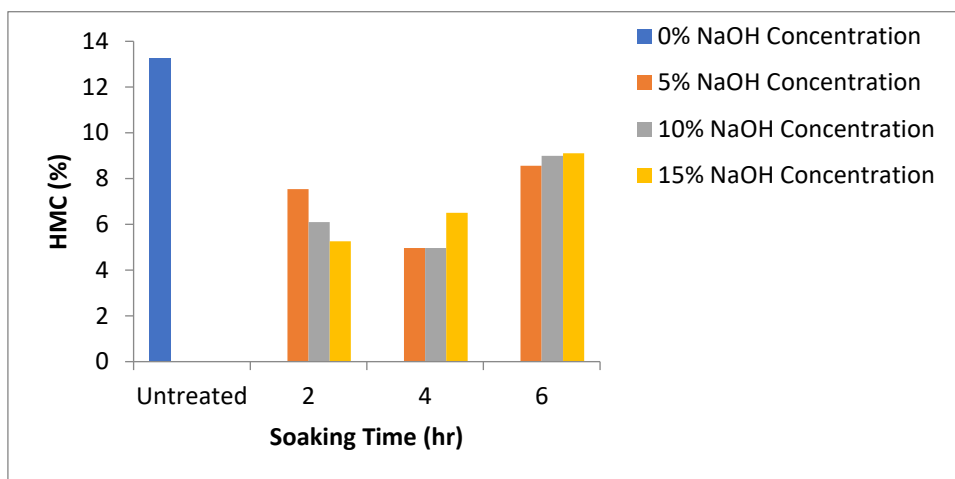


Figure 2: Impact of NaOH treatment parameter on HMC of SBWF

Figure 3 shows the effect of treatment parameter on the LGC of SBWF. From this Figure, there was drastic removal of the LGC from SBWF when the concentration of SBWF improves from 0 to 15 %. At this state, the LGC was reduced from 13.27 % to 5.26 % at a soaking time of 2 hr. The effectiveness of LGC removal between the pre-treated and the unpurified SBWF was found to be 56.74475. This occurs after purification of SBWF in the solution of NaOH, extra components including the LGC has been removed into the soaking solution.

From the process, the SBWF has been fully activated by a hydroxyl group which leads to the introduction of alkoxide in content of the fiber (Oushabi *et al.*, 2017; Palamae *et al.*, 2017). Similar observation was recorded at 4 hr and 5 hr when the soaking time increases, respectively. For 4 hr and 5 hr, the removal percentage between the unpurified and chemically treated

SBWF was observed to be 58.36026 % and 28.19063 %, respectively. The best LGC removal was observed at 15 % wt and 4 hr soaking time. The values of LGC between the modified and unmodified SBWF abridged from 24.76 to 10.31 % at that condition. This corresponds to preceding studies by other research fellows ((Brinchi *et al.*, 2013; Ahmadi *et al.*, 2016; Government *et al.*, 2019; Oushabi *et al.*, 2017; Palamae *et al.*, 2017; Shuhaida and Soh 2016; Barlianti *et al.*, 2015).

The FTIR of unpurified and purified SBWF is represented in Figure 4 (a-b). The peak at 3414.58 cm^{-1} is a character of OH compound in the unmodified SBWF fiber as observed in Figure 4a. In Figure 4b, the same peak was situated at 3439.28 cm^{-1} with a reduction in the transmittance from 106 to 93.5 %; this is an influence of the NaOH on the composition of SBWF. In the same vein, the peak from the

spectrum for the untreated as observed between (2882.01 to 2818.05 cm^{-1}) is a (-COOH-) bond found in the SBWF. This reappeared in the purified SBWF between the peaks 2994.19 to 2808.51 cm^{-1} maintaining reduction in the transmittance which is a further reason for the deduction of unwanted components in the SBWF. The presence of (P-OH) compound was crested at 2352.03 cm^{-1} in Figure 4a after NaOH purification, this peak was noticed to be invisible in Figure 4b. The pyridine compound was traced

at 1612.42 cm^{-1} in the untreated spectrum. For the pre-treated SBWF, the compound was found with a functional group of (C=N) and (C=C) at this time maintaining a jump in the transmittance. Also, at 1379.71 cm^{-1} is an indication of (C=benzene ring stretching), this is due to the presence of HMC and pectin in the SBWF before treatment. In the pre-treated SBWF as situated in Figure 4b, the compound was unnoticed due to the influence of NaOH on the fiber.

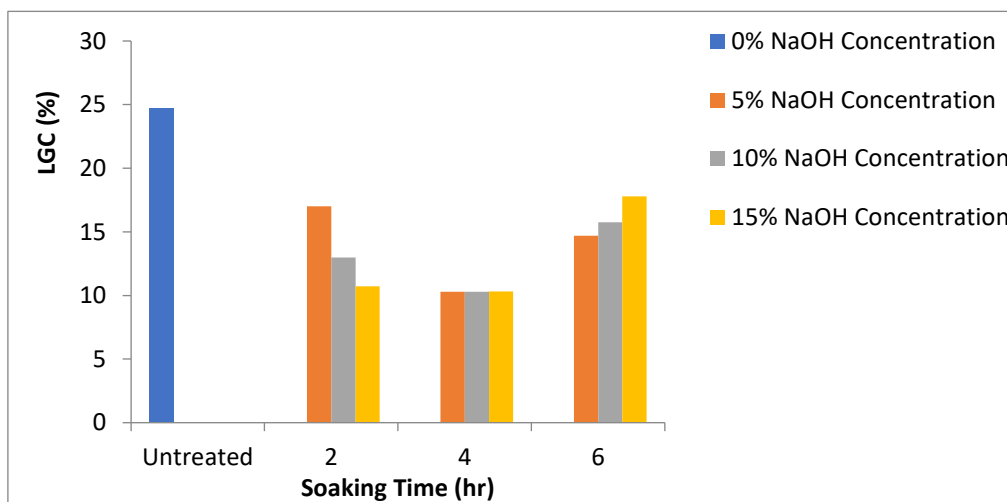


Figure 3: Influence of NaOH treatment on values of LGC of SBWF

At 1200 cm^{-1} in the Figure 4a, the peak indicates the presence of LGC and also 1107.74 cm^{-1} shows C-O-C indicating the presence of CLC in the pre-treated SBWF (Ikramullah *et al.*, 2018). When the SBWF was modified by NaOH, the LGC was found to shrink thereby increasing the CLC as cited at the apex of 1108.11 cm^{-1} . The frequency of (798.06 and 987 to 745.88 cm^{-1} with C-H branch) was captured in crude and the purified SBWF which were the evidence of CLC, respectively. The C-Cl active groups of alkyl halide were also observed in 618.35 cm^{-1} and (618.73 to 521.73 cm^{-1}) for the pure and the mercerized SBWF, respectively. Finally, the movement of the spectrum peak, departure of the active radicals of some compounds between the unmodified and the modified SBWF exposes the alleviation of HMC and LGC under the control of NaOH which amplified the CLC. This

corresponds to prior studies by scholarly journals (Ikramullah *et al.*, 2018; Oushabi *et al.*, 2017).

The SEM micrograph for un-modified and chemically modified SBWF is illustrated in Figure 5 (a-b) above. Smooth array of SBWF particulates was found in the SEM micrograph. Also, more pore space of SBWF was also traced when the fiber is not modified. This leads to lower reaction site when the SBWF is to be used reinforcement to another material. As it was observed in Figure .5b, the particles of the fiber clustered to each other. This leads to better interlocking when the SBWF is used with a substrate for production of new material. This is as a result of after pre-treatment with NaOH, the reaction site when the SBWF is mixed with a substrate in manufacturing of a new material for industrial application has increased; thereby creating

better adhesion with the substrate. When compared with untreated SBWF. Therefore, pre-treated SBWF will have lower water absorption

and higher strength. Close result was analyzed by previous authors (Oushabi, *et al.*, 2017; Reddy *et al.*, 2013).

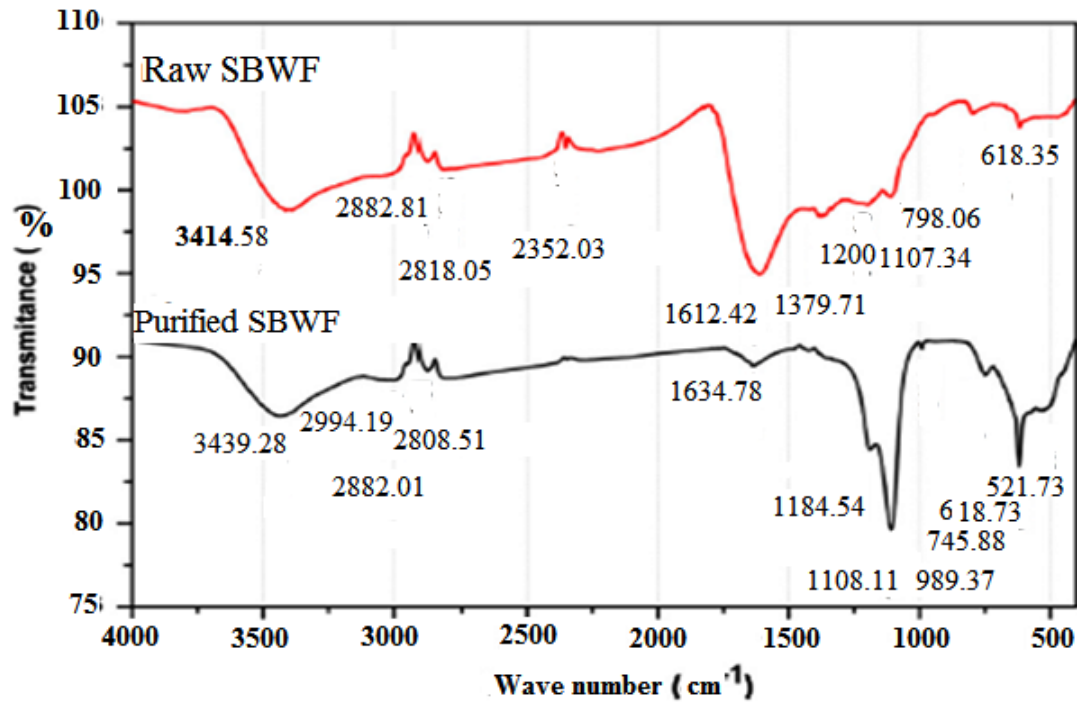


Figure 4: FTIR spectra of SBWF (a) raw (b) after treatment at 10 %w/v NaOH and 4 hr soaking time.

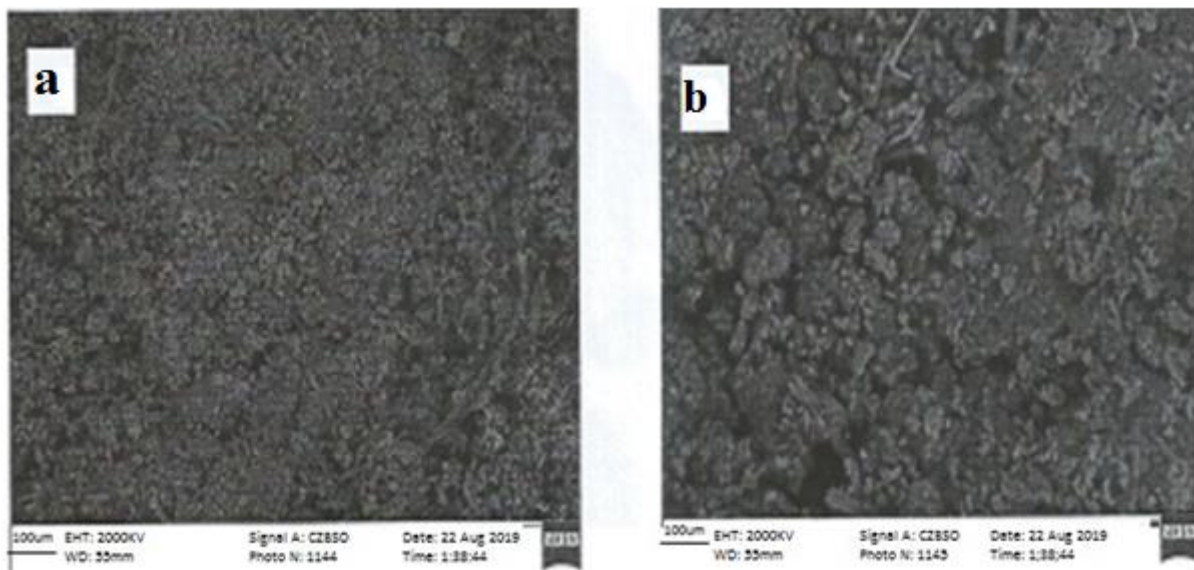


Figure 5: SEM diagram for (a) raw (b) purified SBWF at 10 %w/v and 4 hr

4.0 Conclusion

The research on the composition for the unrefined and refined novel SBWF with the action of NaOH at distinguished concentration and period has been developed. The variation of time and concentrated SBWF enhanced the CLC, diminished LGC and HMC, respectively. The increase in cellulose and reduction in lignin

and hemicelluloses were confirmed on the FTIR and SEM, respectively. The higher concentration of NaOH and moderate exposure due to soaking of SBWF yielded optimal CLC and minimal LGC and HMC, respectively. With this out, the SBWF is a novel component for polymeric-material-fiber composite for car parts production due to amplified amount of CLC.

Recommendations

The novel low priced SBWF is recommended for the constituent of fiber-polymer composite for interior door of a car cabinet.

Acknowledgement

Our sincere gratitude goes to Emeritus Prof. O. D. Onukwuli, who inspired me in this study and my journey to academic field.

References

- Abdul Khalil, H. P. S., Alwani, M. S., & Omar, A. M. (2006). Chemical composition, anatomy, lignin distribution, and cell wall structure of Malaysian plant waste fibers. *BioResources*, 1 (2): 220-232.
- Agu, C. V., Njoku, O. U., Chilaka, F. C., Agbiogwu, D., Iloabuchi, K. V., and Ukazu, B. (2014). Physiochemical properties of lignocellulosic biofibers from south eastern Nigeria: their suitability for biocomposite technology. *African Journal of Biotechnology*, 13 (20): 2050-2057.
- Ahmadi, F., Zamiri M. J., Khorvash M., Ziaee E., and Polikarpov I. (2016). Pre-treatment of sugarcane bagasse with a combination of sodium hydroxide and lime for improving the ruminal degradability: Optimization of process parameters using response surface methodology. *Journal of Applied Animal Research*. 44(1):287–96.
- Atuanya, C. U., Government, R. M., Nwobi-Okoye, C. C. & Onukwuli, O. D. (2014). Predicting the mechanical properties of date palm wood fibre-recycled low density polyethylene composite using artificial neural network. *International Journal of Mechanical and Materials Engineering*, 1(7), 1-20.
- Bogoeva-Gaceva, G., Avella, M., Malinconico, M., Buzarovska, A., Grozdanov, A., Gentile, G. & Errico, M. E. (2007). Natural fiber eco-composites. *Polymer Composites*, 28: 98-107.
- Barlianti, V., Dahnum, D., Hendarsyah, H. & Abimanyu, H. (2015). Effect of alkaline pretreatment on properties of lignocellulosic oil palm waste. *Procedia Chemistry*. 16: 195–201.
- Brinchi, L., Cotana, F., Fortunati, E., & Kenny, J. M. (2013). Production of nanocrystalline cellulose from lignocellulosic biomass: technology and applications. *Carbohydrate Polymers*, 94 (1): 154-169.
- Chen, Y., Tshabalala, M. A., Gao J, Stark, N. M., Fan, Y., & Ibach, R. E. (2014). Thermal behavior of extracted and delignified pine wood flour. *Thermochimica Acta*, 40–4. <http://dx.doi.org/10.1016/j.tca.2014.06.012>
- Dungani, R., Karina, M., Subyakto, Sulaeman, A., Hermawan, D. & Hadiyane, A. (2016). Agricultural waste fibers towards sustainability and advanced utilization: A review. *Asian Journal of Plant Sciences*. 15(1–2):42–55. [http://dx.doi.org/10.3923-ajps.2016.42.55](http://dx.doi.org/10.3923/ajps.2016.42.55).
- Government, R. M., Okeke, E.T., Odera, R. S., Ani A. K., Thaddeus J.& Ikechukwu N.B. (2020a). Significance of alkaline treatment in the composition of mango seed shell fiber for polymer composite application. *Indian Journal of Science and Technology*. 13(21):2168-2174. <https://doi.org/10.1-7485/IJST/v13i21.81>.
- Government, R. M & Onukwuli, O. D. (2025). Optimization of alkali modified breadfruit peel flour-LDPE composite for car mirror casings. *Materials Testing*; 67(3): 471–481.
- Government, R. M., Thaddeus, J., Thompson E. O., Ani, A.K. and Apake D. D. (2020b). Optimizing the cellulose content of shea

- butter bark wood fibre through alkali pretreatment for composite application. *Indian Journal of Science & Technology*. 13(04): 384 - 399. DOI: 10.17485/ijst/-2020/v013104/147288.
- Government, R., Olowokere, J., Odineze, C., Anidobu, C., Yerima, E. and Nnaemeka, B. (2019). Influence of soaking time and sodium hydroxide concentration on the chemical composition of treated mango seed shell flour for composite application. *Journal of Applied Sciences and Environmental Management*, 23(1): 21 - 28.
- Government, R. M., Onukwuli, O. D., & Ani, A. K. (2017). Chemically treated avocado wood flour - LLDPE composite, USA. *Universal Journal of Material Science*, 27-40.
- Government, R. M., Onukwuli, O. D., & Jibatswen, T. Y. (2018). Optimization of chemical treatment of avocado pear wood filler on the properties of LDPE composites, International Conference Processing: Fac. Engineering, UNIZIK. 499-509. 13th-14th August.
- Hattallia, S., Benaboura, A., Ham-Pichavant, F., Nourmamode, A. & Castellan, A. (2002). Adding value to alfa grass (*Stipa tenacissima* L.), soda lignin as phenolic resins. 1. *Lignin characterization*. *Polymer Degradation Stability*, 75: 259–264.
- Hemmasi, A. H., Samariha, A., Tabei, A., Nemati, M., & Khakifirooz, A. (2001). A study of morphological and chemical composition of fibers from Iranian sugarcane bagasse. *American-Eurasian Journal of Agricultural and Environmental Science*, 11 (4): 478-481.
- Herrera-Franco, P. J. & Valadez-Gonzalez, A. (2005). A study of the mechanical properties of short natural-fiber reinforced composites. *Composites Part B: Engineering*, 36: 597-608.
- Hoareau, W., Trindada, W.G., Siegmund, B., Castellan, A. & Frollini, E. (2004). Sugar-cane bagasse and curaua lignins oxidatized by chlorine dioxide and reacted with furfuryl alcohol: characterization and stability. *Polymer Degradable Stability*, 86: 567–576.
- Ikramullah, R., S., Thalib, S. & Huzni, S. (2019). Hemicellulose and lignin removal on typha fiber by alkali treatment. IOP Conference Series: *Materials Science and Engineering*, 352(1): 1-6
- Jawaid, M. & Abdul-Khalil, H. P. S. (2011). “Effect of layering pattern on the dynamic mechanical properties and thermal degradation of oil palm-jute fibers reinforced epoxy hybrid composite,” *BioResources*, 6: 2309-2322.
- Johar, N., Ahmad, I. & Dufresne, A. (2012). Extraction, preparation and characterization of cellulose fibres and nanocrystals from rice husk. *Industrial crops and Products*, 37 (1): 93-99.
- Lazim, Y., Salit, S. M., Zainudin ES, Mustapha M, & Jawaid M. (2014). Effect of alkali treatment on the physical, mechanical, and morphological properties of waste betel nut (*Areca catechu*) husk fibre. *BioResources*, 9(4):7721–36.
- Mahyati, P., A. R, Djide, M. N., Taba, D. P., Rauf P., A, & Nasir D. M, (2013). Biodegradation of lignin from corn cob by using a mixture of phanerochaete chrysosporium, lentinus edodes and pleurotus ostreatus. *International Journal of Scientific & Technology*. 2(11): 1-4.
- Marwan, M. & Nasim, U. (2016). Experimental analysis of compressed earth block (CEB) with banana fibers resisting flexural and

- compression forces. *Case Studies in Construction Materials*, 5; 53-63.
- Muryanto, T. E., Abimayu, H., Cahyono, A., Cahyono, E. T. & Sudiyani, Y. (2015). Alkaline delignification of oil palm empty fruit bunch using black liquor from pretreatment. *Procedia chemistry*. 16:99–105.
- Mwaikambo, L. Y. & Ansell, M. (2002). “Chemical modification of hemp, sisal, jute and kapok fibers by alkalization,” *Journal of Applied Polymer science* 84: 2222-2234. DOI:10.1002/app.10460.
- Nachtigall, S. M. B., Cerveria, G. S., & Rosa, S. M. L. (2007). New polymeric-coupling agent for polypropylene/wood flour composites. *Polymer Testing*, 26: 619-628.
- Netral, B., Sabu, T., Chapal, K. D., Rameshwar, A. (2012). Analysis of morphology and mechanical behaviors of bamboo flour reinforced polypropylene composites. *Nepal Journal of Science Technology*, 13(1): 95-100.
- Obasi, H. C. (2015) Peanut Husk Filled Polyethylene Composites: Effects of Filler Content and Compatibilizer on Properties. *Journal of Polymers*. p. 1–9.
- Okeke, E. T; Government, R. M.; Apake, D. D. & Ani, A. K. (2023). Effects of sodium hydroxide on the compositions of shea butter bark wood fiber for polymeric composite production in structural application. *Journal of Applied Science, Environment and Management*, 27(7): 1423-1429.
- Oushabi, A., Sair, S., Oudrhiri Hassani, F., Abboud, Y., Tanane, O., & El Bouari, A. (2017). The effect of alkali treatment on mechanical, morphological and thermal properties of date palm fibers (DPFs): Study of the interface of DPF–Polyurethane composite. *South African Journal of Chemical Engineering*, 23:116–23. <http://dx.doi.org/10.1016/j.sajce.-2017.04.005>.
- Palamae, S., Dechatiwongse, P., Choorit, W., Chisti, Y., & Prasertsan, P. (2017). Cellulose and hemicellulose recovery from oil palm empty fruit bunch (EFB) fibers and production of sugars from the fibers. *Carbohydrate Polymers*, Vol. 155, Elsevier Ltd.; 491-497. <http://dx.doi.org/10.1016/j.carbpol.2016.09.004>.
- Ray, D., Sarkar, B. K., Rana, A. K., & Bose, N. R. (2001). Effect of alkali treated jute fibres on composite properties. *Bulletin of Materials Science*, 24 (2): 129-135.
- Reddy, K. O., Reddy, K. R. N., Zhang, J., Zhang, J., & Varada, R. A. (2013). Effect of alkali treatment on the properties of century fiber. *Journal of Natural Fibers*. 10(3): 282–96.
- Rowell, R. M. (1998). Property Enhanced natural fiber composite material based on chemical modification, in science and technology of polymers and advanced materials, Prasad P.N., Mark J.E., Kendil S.H. & Kafafi Z.H Eds., page 717-732, Plenum Press, New York.
- Rowell, R. M., Han, J. S., & Rowell J. S. (2000). Characterization and factors effecting fiber properties in natural polymers and agro fibers-based composites. *Natural polymers and bio-based composites*, 115–135.
- Sari, N. H., Wardana, I. N. G., Irawan, Y. S., Siswanto, E. (2017). The effect of sodium hydroxide on chemical and mechanical properties of corn husk fiber. *Oriental Journal of Chemistry*, 33(6):3037–42.
- Setswalo, K., Namoshe M., Kutua, S., Oladijo O. P. & Samson, B. (2017). Effect of thermal and alkali treatment on pterocarpus

- angolensis (mukwa) wood flour. *Procedia Manufacturing*, 7:205–10.
- Shuhaida, H. & Soh, K. G. (2016) Effect of sodium hydroxide pretreatment on rice straw composition. *Industrial Journal of Science Technology*, 9(21): 1-9.
- Srinivas, K., A. Lakshumu N., & RajuBahubalendruni, M.V.A. (2017). "A Review on chemical and mechanical properties of natural fiber reinforced polymer composites," *International Journal of Performability Engineering*, 13.2: 189
- Suryanto, H., Marsyahyo, E., Irawan, Y. S. & Soenoko, R. (2013). Effect of alkali treatment on crystalline structure of cellulose fiber from mendong (*Fimbristylis globulosa*) straw. *Key Engineering Materials*, 2013; 594–595
- Taj, S., Munawar, M. A., & Khan, S. U. (2007). Review: Natural Fibre Reinforced Polymer Composites and Processing. *Pakistan Academy of Science*, 44 (2): 129 – 144.
- Valadez-Gonzalez, A., Cervantes-Uc, J. M., Olayo, R. and Herrera-Franco, P. J. (1999). Effect of fiber surface treatment on the fiber-matrix bond strength of natural fiber reinforced composites, *Composites Part B: Engineering*, 30: 309-320.
- Wambua, P., J. Ivens, & Verpoest. I. (2003). Natural fibers: Can they replace glass in fiber reinforced plastics? *Composites Science and Technology*, 63: 1259–1264.
- Wang, Z., Li, J., Barford, J. P., Hellgradt, K. & Mckay, G. (2016). A comparison of chemical treatment methods for the preparation of rice husk cellulosic fibers. *International Journal of Environmental & Agriculture Research*, 2(1): 2454–1850. <http://www.ijoeear.com/Paper-January-2016/IJOEAR-JAN-2016-11>.
- Weyenberg, I. V., Truong, T. C., Vangrimde, B., Verpoest, I. (2006). Improving the properties of UD flax fiber reinforced composites by applying an alkaline fiber treatment. *Composites Part A: Applied Science Manufacturing*, 37 (9): 1368-1376.
- William, J. & Patrick, C. (2017). Improving the properties of banana fiber reinforced polymeric composites by treating the fibers|| 3rd international conference on natural fibers: Advanced Materials for a Greener World, ICNF 2017, 21-23 June 2017, Braga, Portugal.
- Wong, K. J., Zahi, S., Low, K. O., & Lim, C. C. (2010). Fracture characterization of short bamboo fibre reinforced polyester composites. *Materials & Design*, 31(9): 4147-4154. [http://dx.doi.org/10.1016-j.matdes.2010.04.029](http://dx.doi.org/10.1016/j.matdes.2010.04.029).
- Wu, J., Yu, D., Chan, C., Kim, J., & Mai, Y. (2000). Effect of fiber pre-treatment condition on the interfacial strength and mechanical properties of wood fiber/paper composite. *Journal of Applied Polymer Science*, 76: 1000-1010.