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# Evaluation of Tensile Strength of Cattle Horn Fiber-Reinforced Recycled Low Density Polyethlene Composite

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**Research Article**

**Abstract**

*This work presents cattle horn as new reinforcement natural fiber in thermo plastic composite production. And in particular, it evaluates the effect of different cattle horn fiber volume fraction, cattle horn fiber length sand treatment of the fiber with NaOH on recycled low density polyethylene (RLDPE) with respect to tensile strength property of the composite. This was done to contribute to the latest effort of replacing synthetic fibers which are non-renewable, decomposable and recyclable with natural fiber such as cattle horn fiber. Nine different samples of composites were produced using compounding and compression method. The disposed water sachet plastics acted as the source of RLDPE used in the research. Likewise, the cattle horns were picked randomly, cleaned and machined into fibers with the lengths 6mm, 12mm and 18mm, then modified with 0.1,0.2 and 0.3M of NaOH. Moreover, the proportions of matrix materials (RLDPE) were variedby 10% interval ranging from 70% to 90% and fiber loading from 10-30%.L-9 Taguchiarray method was used to design and analyze the results in order to find the best combination of fiber length, fiber and matrix volume fraction, and proportion of NaOH that would give the optimum tensile strength. The results revealed that sample with 0.1M, 6mm cattle horn fiber length (CHFL) and 10% cattle horn fiber volume (CHFV) fraction has maximum tensile strength. This means that, the tensile property of cattle horn reinforced RLDPE did not depend on the higher fiber loading. Also, NaOH treatment contributed highest percent of 47.08% to the tensile strength while CHFV contributed 11.71% but tensile strength decreases with increment in fiber length.*

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**Keywords**
cattle horn fibre; composite; plastic; recycling; and tensile strength

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## 1. Introduction

Investigating the novel natural fiber (NF) in developing and producing advanced composite materials (ACMs) is becoming most recent research domain among the materials' scientists and engineers. This occurred as a result of serious and unavoidable request to switch over from synthetic fibers which are non-renewable, decomposable and recyclable at their end of life and likewise costly. For natural fibers to replace well the synthetic, their properties have to be studied and evaluated (karimah *et al*., 2021).

One of most important property of engineering materials that need to be studied and evaluated for natural fiber is Tensile Strength (TS) because it determines the capability of material to resist a load without undue deformation, or rupture or failure and this is inherent and in-built property in materials which are conventionally determined by experimentation. Thus, one of the utmost tests to carry out in examining this is tension/tensile test (Saba, *et al*.,2019). Different researches have been conducted to determine TS property of composites in order to suggest or recommend the material for different area of engineering application. A study of the impact of different fiber volume fraction (FVF) on TS properties of Kenaf/E-glass reinforced hybridpoly propylene (PP) composites was done by Sosiati, *et al*. (2018).The results showed that the TS of composites was gradually coming down with the increase of the fiber loading.

Furthermore, a comparative study on TS behavior of plant and animal fiber reinforced composites was conducted by some researchers where untreated rice straw and chicken feather fibers (RSF & CFF) was explored disjointedly to reinforce polyester thermo setting res in (PTR) matrix for the development of composite samples. The result of the study showed that tensile strength decreases with increase in the fiber loading till an optimum fiber loading before it rose up again (Ganesh and Rekha, 2015).

Likewise, another comparative study of TS properties on thermoplastic and thermo setting polymer composites were carried out. PTR matrix was employed as thermo setting polymer (TSP) while PP as thermo plastic polymer (TPP). Both were explored to bind glass fiber and their TS were compared. The result revealed that thermo setting composite has better tensile properties than thermoplastic (Benin, *et al*., 2015).

This work presents the use of cattle horn (CH) because it consists of keratin and nearly all keratinized materials are regarded as reinforcing fibers for composite development (Mckittrick, *et al*., 2012). Also, CH is abundant in Nigeria, specifically, northern part, and is under-utilized to the extent that its disposal becomes a problem. In the past, cow horn was being exported to the developed countries which also serve as source of revenue to this nation. Nowadays, many countries have imposed restrictions on importation of animal by-products in order to curtail the spreading of contagious diseases. Currently apart from loss of income, disposal also becomes problem (Abdullahi and Salihi, 2011; Abdullahi, *et al*., 2014).

Equally, empty 'Pure Water' plastic bags/sachets are disposed off indiscriminately in this country. This poses a great risk to the environment in terms of land and water pollution. It is noticeable that, the so called pure water cannot be absolutely and conveniently substituted or eradicated by bottle/table water due to high level of poverty. Therefore, there is need to find ways of recycling the released empty pure water sachets into another useful material. This waste is very light in weight and it falls under polythene family which can bind the fibre in the development of thermoplastic composite materials, as ithas been explored as matrix material in the development of bumper composite materials as well as other different thermo plastic composite materials (Samotu *et al*.,2015). This work evaluated the tensile strength of different samples produced from cattle horn fiber reinforced RLDPE composites.

## 2. Materials and Methods

### 2.1 Materials

Experimental materials used in this study are cattle horn, waste pure water sachet (recycle low-density polyethylene), conventional oven, lathe machine, electronic weighing balance, compounding machine, hydraulic hot press, shredder, metal mold, universal testing machine, oven, beaker and desiccator as well as sodium hydroxide (NaOH), soap.

### 2.2 Materials Preparation

Cattle horn was collected randomly from Mubi north abattoir and then washed with soapy water so as to clean its outer surface from dirt, contamination and debris. Thereafter, it was sun dried for 3days as shown in Figure 1. Later it was further dried using conventional oven at 100ºC for 26 hours to completely remove moisture in the horn (Abdullahi and Salihi, 2011; Abdullahi, *et al*., 2014; Mogaji, *et al*., 2017; Ambali, *et al*., 2019). Consequently, it was machined into fibers of lengths 6, 12 and 18mm as shown in Figure2.

Waste pure water sachets were collected from different various refuse dumps along Ahmadu Bello way in Mubi Adamawa State. The sachet was turned opened and Washed with clean water and detergent in order to remove dirt, dust and any other contaminants. Thereafter, it was cut to smaller sizes o f1-3mm pellets using shredder shown in Figure 3. Then, it was air dried for10hrs (Atuanya, *et al*., 2011; Idowu and Adekoya, 2015).

Figure1: Sun Dry of Cattle Horn

Figure 2: Production of Cattle Horn Fiber on Lathe machine

Figure3: Waste Pure Water Sachets on Shredder

Sodium hydroxide was purchased and used in different molarity ranging from 0.1 to 0.3M for fiber modification. The modification was done by soaking the Fiber with 0.1, 0.2 and 0.3M of NaOH for 4 hours. Then, it was removed, washed and dried at a room temperature (Peças, *et al.*, 2018; kumar, *et al.*, 2016).

## 2.3 Experimental Design (ED)

Taguchi Orthogonal Array (TOE) method was employed for experimental design to determine the parameters influencing the process and the levels at which these parameters should be combined. In addition, three factors and three levels were selected in this work. These are cattle horn fiber length (CHFL),Cattle horn fiber volume (CHFV) and Sodium hydroxide ratio (NaOH) and their levels as shown in Table 1.This design system has been employed in many researches (kumar, et al., 2016; Tudu, 2009; Hamza, et al., 2017; Kim,2013). The results of Taguchi experimental design is shown in Table 2.

Table1: Design of Experiments Parameters Levels

| Factor/ Level | NaOH (N) | CHF length (mm) | CHF volume (%) |
|---|---|---|---|
| 1 | 0.1 | 15-25 | 10 |
| 2 | 0.2 | 30-40 | 20 |
| 3 | 0.3 | 45-55 | 30 |

Table 2: L9 (33) Taguchi Orthogonal Array Matrix

| Sample | Sample ID | NaOH (N) | CHF length (mm) | CHF volume (%) |
|---|---|---|---|---|
| 1 | $N_1 L_1V_1$ | 0.1 | 6 | 10 |
| 2 | $N_1L_2V_2$ | 0.1 | 12 | 20 |
| 3 | $N_1L_3V_3$ | 0.1 | 18 | 30 |
| 4 | $N_2L_1V_2$ | 0.2 | 6 | 20 |
| 5 | $N_2L_2V_3$ | 0.2 | 12 | 30 |
| 6 | $N_2L_3V_1$ | 0.2 | 18 | 10 |
| 7 | $N_3L_1V_3$ | 0.3 | 6 | 30 |
| 8 | $N_3L_2V_1$ | 0.3 | 12 | 10 |
| 9 | $N_3L_3V_2$ | 0.3 | 18 | 20 |

## 2.4 Production of Composite

The shredded recycle low density polyethylene (RLDPE) was melted using compounding machine. Then the modified fibers were introduced into the Melted RLDPE at temperature 150ºC while rolls were rotated at a speed of 50-70 rev/min for a period of 10 minutes as shown in Figure 4.

Besides, the compounding product was then charged into a metal mold of 250x250x5mm which was already preheated to about 100ºC and coated with releasing agent. This is to grant virtually uniform cooling and ease the removal of sample from the mold after cooling. Subsequently, it was quickly transferred into hydraulic hot press shown in Figure 5 where the mold was subjected to a pressure of 0.4MN/m2 at temperature of 150ºC for further compaction for 5 minutes, here after it was allowed to cures (Samotu, *et al*., 2015;Kumi-Larbi, *et al*., 2018; Ogunsile and Oladeji, 2016; Bala, 2016).

Figure 4: Production of Composite in Compounding Machine

Figure 5: Compression of the Composite

## 2.5 Composite Testing

After production of the composite, tensile properties test was conducted to evaluate the behavior of a material under different forms of tensile loading in accordance with ASTMD 638. Samples were prepared into tensile dimension based on aforementioned standard. This is shown in Figure 6. The universal testing machine in Mechanical Engineering Department, Bayero University Kano was employed as shown in Figure 7. The dimensions, gauge length and cross-head speeds were chosen according to the standard. So, the tensile strength ($Ts$) was determined using Equation 1. The above mentioned procedure was repeated for all the samples (Jiyanthi, 2013; Shehu,2016).

$$T_s = \frac{W_u}{lt} \tag{1}$$

$W_u$ is the ultimate failure load (N), $l$ $and$ $t$ is mean width and thickness of sample (mm), respectively. ($T_S$) is the ultimate tensile strength.

Figure 6: Tensile Test Samples

Figure 7: Sample Loaded on UTM

Experimental results of tensile property for the nine samples obtained from L9 orthogonal array were processed by Minitab for Taguchi analysis, models and optimization. During the analysis, signal to noise (S/N) ratios was generated for the property. Signal connotes the desirable value (mean) while ‘noise denotes undesirable value (standard deviation from the mean). S/Nratio commonly known as measure of quality Characteristics and deviation from the desired value (signal). In generating thisratio, the larger-the-better criterion equation was employed, because the higher the tensile strength of material, the more desirable the material for engineering applications. Additionally, this is in compliance with other research (Navaneethakrishnan and Athijayamani, 2015; Kumar, *et al*., 2017; Mohamad, *et al*., 2019)

## 3. Results and Discussion

It can be seen in Table 3 that sample 1has highest S/Nratio, designating that it is the best sample that offers maximum tensile strength value based on the larger the better condition. Comparison of the effect of the three experimental factors (NaOH, CHFL and CHFV) on tensile strength of the composites was achieved from the analysis through delta and rank in the signal to noise (S/N) ratio response shown in Table 4. NaOH factor is the most effective factor that contributed greatly to the tensile strength values, then followed by the CHFL while CHFV showed the least effect. This also confirmed by the graph plotted in Figure2 because NaOH factor has highest mean of S/Nratio than the rest of process parameters.

From Figure 8, it can be comprehended that sample 1 has highest tensile strength, followed by sample 4, then sample 6. It can be observed from those samples that tensile property did not depend on the higher fiber loading. This means that the lower the fiber loading, the higher the tensile strength of the developed composite. This is inconformity with Sosiati, *et al*. (2018).

Table 3: The Result of Experimental Factors and S/NRatio for Tensile Strength

| Experiment number | Control factors | | | Experimental | S/N ratio |
|---|---|---|---|---|---|
| | NaOH (N) | CHFL (mm) | CHFV (%) | Tensile Strength (Mpa) | Tensile Strength (dB |
| 1 | 0.1 | 6 | 10 | 7.451 | 17.4443 |
| 2 | 0.1 | 12 | 20 | 5.888 | 15.3994 |
| 3 | 0.1 | 18 | 30 | 5.723 | 15.1525 |
| 4 | 0.2 | 6 | 20 | 6.974 | 16.8696 |
| 5 | 0.2 | 12 | 30 | 7.057 | 16.9724 |
| 6 | 0.2 | 18 | 10 | 6.385 | 16.1032 |
| 7 | 0.3 | 6 | 30 | 5.739 | 15.1767 |
| 8 | 0.3 | 12 | 10 | 5.943 | 15.4801 |
| 9 | 0.3 | 18 | 20 | 5.200 | 14.3201 |

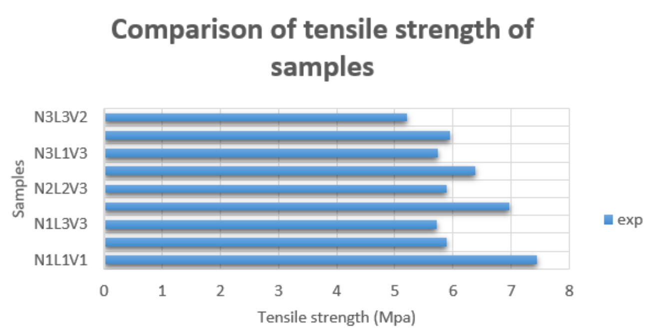


Figure 8: Plot for Comparison of Samples of Tensile Results

Table 4: Response Table of Signal to Noise Ratios for Tensile Strength (Larger is better)

| Level | NaOHN | CHFL | CHFV |
|---|---|---|---|
| 1 | 16.00 | 16.50 | 16.34 |
| 2 | 16.65 | 15.95 | 15.53 |
| 3 | 14.99 | 15.19 | 15.77 |
| Delta | 1.66 | 1.30 | 0.81 |
| Rank | 1 | 2 | 3 |

Table 5 shows ANOVA results for tensile strength. This table presents the amounts of contribution of each factor on tensile strength of the composite in percentage. NaOH factor contributed highest percent of 47.08% to the tensile strength due to its ability to remove the dirt and reduce the brittleness in fibers so as to enable better adhesion of fiber to the matrix. While CHFL and CHFV contributed 30.32% and 11.71% respectively to the tensile strength of the composite.

It can be comprehended directly from the optimization curve in Figure 9 that the peak TS property can be accomplished if 0.2M of NaOH, 6mm CHFL and 10% CHFV areused. Additionally, it establishes the fact that, NaOH factor contributed higher than the other factors because it has highest mean of S/Nratio than the rest of process parameters. This similar observation was also reported by Kumar, *et al*. (2017) and Bodur, and Bakkal (2019). The result of the investigation further showed that increment in fiber length above 6mm led to a decline in tensile properties. However, tensile strength was found to increase as fiber loading increase to 20% and then decreases with further increase in the fiber volume fraction beyond this.

Table5: Results of Analysis of Variance (ANOVA) for Tensile Strength

| Source | Degree of freedom | Sum of squares (SS) | Mean square (MS) | F ratio | Contribution (%) |
|---|---|---|---|---|---|
| NaOH (N) | 2 | 2.1194 | 1.0597 | 4.32 | 47.08 |
| CHFL (mm) | 2 | 1.3646 | 0.6823 | 2.78 | 30.32 |
| CHFV (%) | 2 | 0.5272 | 0.2636 | 1.08 | 11.71 |
| Error | 2 | 0.4902 | 0.2451 | ------ | 10.89 |
| Total | 8 | 4.5013 | ---- | ------ | 100 |

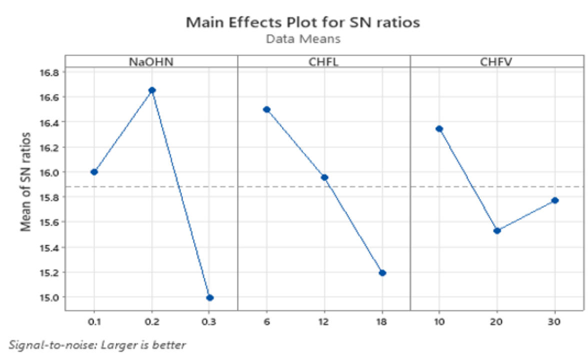


Figure 9: Effect of Process Parameters on Average S/Nratio for Tensile Strength

## 4. Conclusion

Based on the results and discussion the following conclusions are made:

1. There is a limit to the amount fiber loading with which the tensile property of cattle horn reinforced RLDPE increase.
2. From the three factors used, NaOH factor demonstrated highest percent of contribution 47.08% to the tensile strength While CHFL and CHFV contributed 30.32% and 11.71% respectively
3. Increment in fiber length has negative effect on tensile properties of the developed composite,
4. Optimum tensile strength was suggested to be accomplished when parameter combination of 0.2M of NaOH, 6mm CHFL and10% CHFVwas employed,
5. Cattle horn fibers was successfully used to reinforce and improve the tensile property of RLDPE polymer.

## References

Abdullahi, U. and Salihi, A. (2011). Characterization and Iinvestigation into Potential Application of Kano Cattle Horn. Journal of Engineering and Technology, VI(1&2), 32-40.

Abdullahi, U., Salihi, A. and Ali, A. B. (2014). Hardness Behaviour of Thermoplastic Cattle Horn Using Nano-indentation Technique. Asain Journal of Engineering and Technology, 2(2), 168-174. 18.

Ambali, I. O., Shuaib-Babata, Y. L., Alasi, T. O., Aremu, I. N., Ibrahim, H. K., Elakhame, Z. U, and Abdulrahman, S.O. (2019). Suitability of Cow Horn as Filler in an Epoxy Composite. J. Appl. Sci. Environ. Manage, 23(3), 475-482.

Atuanya, C. U., Ibhadode, A. O. A. and Igboanugu, A. C. (2011). Potential Of Using Recycled Low-Density Polyethylene In Wood Composites Board. Tribology In Industry, 33(01), 11-17.

Bala, M. B. (2016). Production And Characterization Of Recycled Ldpe/Periwinkle Shell Particulate Composite. Msc Dissertation, Ahmadu Bello University Zaria, Metallurgical And Material Engineering, Zaria.

Benin, M. A, Retnam, B. S. J, Ramachandran,M.,Sivapragash, M. and Dhas, J.E.R. (2015). Comparative study of tensile properties on Thermoplastic & Thermosetting polymer composites. International Journal of Applied Engineering Research, 10(11), 10109-10113.

Bodur, M. S. and Bakkal, M. (2019). Young's Modulus Estimation Techniques For The Randomly Oriented Natural Ffiber Reinforced Composites: Finite Element Analysis And Analytical Models. Pamukkale University Journal Of Engineering Sciences, 25 (4), 454-461. Doi:10.5505/Pajes.2019.88864

Ganesh, B. N and Rekha, B. (2015). A Comparative Study on Tensile Behavior of Plant and Animal Fiber Reinforced Composites. International Journal of Progressive Sciences and Technologies (IJPSAT), 1(1), 14-17.

Hamza, K., Shash, A. Y. and Abdrabou, M. (2017). Application Of Short Fibers Reinforced Composites In Power Transmission Coupling. Latin American Journal Of Solids And Structures 14 , 14, 1789-1803.

Idowu, I. A. and Adekoya, L. O. (2015). Effects Of Filler On Some Mechanical Properties Of Recycled Low-Density Polyethylene Composites. Proceedings Of The Oau Faculty Of Technology Conference, (Pp. 384-387).

Jiyanthi, S. (2013). An Investigation On Use Of Natural Fiber Reinforced Thermoplastic Composites For The

Automotive Bumper Beam. Phd Thesis, Anna University, Mechanical Engineering.

Karimah, A., Ridho, M. R., Munawar, S. S.,…Siengchin, S. (2021). A Comprehensive Review on Natural Fibers:Technological and Socio-Economical Aspects. Polymer 13 (4280) https: //doi.org/10.3390/polym13244280

Kim, N.K, Bhattacharyya, D. and Lin, R. J. T. (2013). Multi-Functional Properties Of Wool Fibre Composites. Advanced Materials Research -08-30, 747, 8-11.

Kumar, S. A. R. Hashmi, S. A. R, Nimanpure, S. and Naik, A. (2017). Enhanced Dynamic Mechanical Properties Of Kenaf Epoxy Composites. Advanced Materials Proceedings, 749-757.

Kumar, D., Rajendra, B. S. and Sangeetha, D. (2016). Investigation On Tribological Properties Of Horn Fiber Reinforced Epoxy Composites. International Journal Of Mechanical & Mechatronics Engineering Ijmme-Ijens, 16(3), 79-87.

Kumi-Larbi J. A., Yunana, D., Kamsouloum, P., Webster, M., Wilson, D.C and Cheeseman, C. (2018). Recycling Waste Plastics In Developing Countries: Use Of Low-Densitypolyethylene Water Sachets To Form Plastic Bonded Sand Blocks. Waste Management, 80, 112–118.

Mckittrick, J., Chen, P.-Y., Bodde, S.G., Yang, W., Novitskaya, E. E. and Meyers M.A. (2012). The Structure, Functions, and Mechanical Properties of Keratin. Journal of the Minerals, Metals & Materials Society Vol. 64, (4). doi: 10.1007/S11837-012-0302-8.

Mogaji, P. B., Abioye, T. E and Ohuruogu, N. O. (2017). Development of Epoxyresin Composite Reinforced with Cow Horn and Cassava Particles for Car Dashboard. Journal of Engineering and Engineering technology, 11(1), 56-51.

Mohamed, S. A. N., Zainudin, E. S., Sapuan, S. M., Deros, M. A. M. and Arifin, A. M. T. (2019). Integration Of Taguchi-Grey Relational Analysis Technique In Parameter Process Optimization For Rice-Husk Composite. Bioresources.Com 14(1) Pp 1110-1126

Navaneethakrishnan, S. and Athijayamani, A. (2015) Taguchi Method For Optimization Of Fabrication Parameters With Mechanical Properties In Fiber And Particulate Reinforced Composite Springer, Doi 10.1007/S12588-015-9128-X

Ogunsile, B. O. and Oladeji, T. G. (2016). Utilization Of Banana Stalk Fiber As Reinforcement In Low Density Polyethylene Composite. Revista Matéria, 21(4), 953–963.

Peças, P., Carvalho, H., Salman, H. and Leite, M. (2018). Natural Fiber Composites And Their Applications: A Review. Journal Of Composite Science, 2(66), 1-20. Doi:10.3390/Jcs2040066.

Saba, N., Jawaid, M. and Sultan, M.T.H. (2019). An Overview of Mechanical and Physical Testing of Composite Materials. In Mechanical and Physical Testing Of Biocomposites, Fibre-reinforced Composites and Hybrid Composite (pp. 1-12). Woodhead Publishing Series in Composite Science and Engineering.

Samotu, I. A., Dauda, M., Anafi, F. O. A and Obada, D. O. (2015) Suitability Of Recycle Polyethylene/Palm Kernel Shell-Iron Filings Composite For Automobile Application, Triobology Industry, Vol.7, ( 2), 142-153

Shehu, U. (2016). Development Of Baobab/Sisal Reinforced Low-Density Polyethtlene Hybrid Composite. Msc. Dissertation, Ahmadu Bello University, Zaria, Nigeria, Department Of Chemical Engineering.

Sosiati, H., Shofie, Y.A. and Nugroho, A.W. (2018). Tensile Properties of Kenaf/E-Glass Reinforced Hybrid polypropylene (PP) Composites with Different Fiber Loading. Evergreen Joint Journal Of Novel Carbon Resource Sciences & Green Asia Strategy, 5(02), 1-5

Tudu, P. (2009). Processing And Characterization Of Natural Fiber Reinforced Polymer Composites. Phd Thesis, National Institute Of Technology, Rourkela, Mechanical Engineering, Rourkela.