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PROXIMATE AND THERMOGRAVIMETRIC ANALYSIS OF UNTREATED AND TREATED BANANA FIBER

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Abstract

The objective of this research work is to improve the physical and thermal properties of banana fiber, where the fibers are from the natural origin. Several fabrication methods were tried to consolidate them in polymeric, freely reinforcement along with personating of the recently developed compounds, factors affecting the atmospheric states are communicated. Complications appearing elsewhere during the managing of green compounds along with seeking out built to reduce those difficulties are too expressed. Attempts to forged recently developed green compounds along with assessing their production in practical applications are awarded. Chemical usage of convinces such improvement where fibers were submerged in 6% NaOH aqueous mixture (w/v) for 2 hours at ambient temperature (1:15 fiber-to-solution weight ratio). The washed fiber was rigorously rinsed with purifying aqua to separate too much NaOH from the surface and oven-dried at 110oC.

Keywords: Chemical treatment, Fiber-reinforcement, Natural fiber, NaOH.

1. INTRODUCTION

Creators, as well as construction industries, are continually explored for recently developed along with an enhanced substance and manufacture methods to enhance minimum values and gain margins. The self-propelled, energy along with Transportation Company's advantage greatly from lighter substances along with reprocessing parts because of better energy effectiveness. Because of the growing request for ecological substances, there is an enlarging attentiveness in bio-based or "green compounds", too mentioned even as natural substances. Natural fibers are sustainable along with acquired from natural assets that confer various benefits, comprising small density, allowable strength to weight ratio attributes, better sound subsiding potentiality, small abrasive, little price, greater environmentally-safe, and the alive of huge assets. Also besides, this can be carbonized for power rehabilitation, since a better heat of combustion has been them. Several investigators have utilized the matrix likely of the sugarcane, rice, wheat straw, along with jute for producing thermoplastic and thermoset compounds employing many dissimilar methods. Thermogravimetric experimental analysis is a technique of temperature exploration in which the weight of sample is computed with respect to time as the temperature swap. Then get concerning physical phenomena such as phase transitions, absorption, adsorption, and desorption. Learning on the thermal attributes of banana fiber composites was being carried out in the thermogravimetric analysis (TGA) [1].

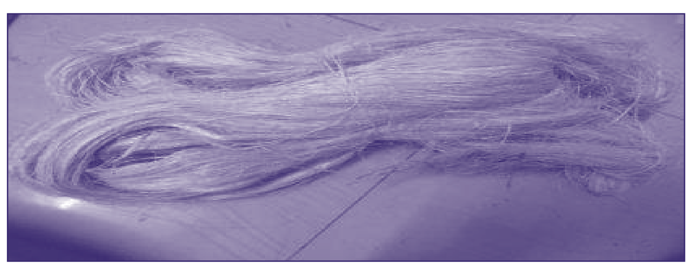
2. MATERIALS AND METHODS

2.1 Banana fibers: It receives from the stem of the banana herb are a woody fibers with relatively better. Banana fibers offer remarkable benefits like feebleness, suitable inflexibility, and mechanical things, and maximum disposable. Moreover, they are recyclable and biodegradable. There has been a lot of research on the use of natural fibers in reinforcements. Lignins are correlated with hemicellulose and vital a principle part freely decompose stopped to the lignocellulosic substance. These are the configuration of banana pseudo stalk acquired to the components experiments as given in Table 1 [2].

Table 1. Concerning plant configuration of studious pseudo-stem strands

S. No.	Constituents	Percentage
1.	Cellulose	31.27 ± 3.61
2.	Hemicellulose	14.98 ± 2.03
3.	Lignin	15.07 ± 0.66
4.	Extractives	4.46 ± 0.11
5.	Moisture	9.74 ± 1.42
6.	Ashes	8.65 ± 0.10

Figure 1. Banana fibers



2.2 Banana fiber ash: Banana fiber ash, a residue of untreated particulate banana fiber burning in the muffle furnace at 500oC for 5 minutes. These ash residues are during the proximate analysis of particulate banana fiber to determine the percentage of ash content in banana fiber.

Figure 2. Banana fiber ash

2.3 Methodology

- Draw up the issue and aim of the research article.
- Extraction of banana fiber from the stalk of banana plant.
- Fiber Treatment (untreated fibre and treated fibre by 6% NaOH)
- Deciding the volume fractions.
- Fabrication of banana fibers.
- Testing of treated and untreated banana fibers.
- Evaluation of results.
- Analyzing the results and graphs.

2.3.1 Extraction of banana fibers: The banana fiber is received by the local sources and banana plants. The banana fiber in the form of non–woven fiber was utilized in this project. The strands were discrete mechanically by the banana stalk along with were become dry. The

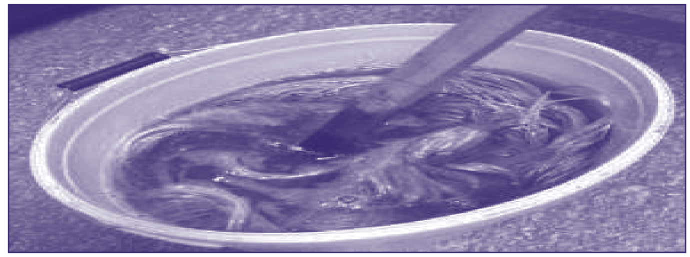
procedure for the extraction of banana fiber is that firstly sun-dried for eight hours and then in hot air oven-dried for 24 hours at 100oC to reduce the water particles comprise in the fibers.

2.3.2 Fiber chemical treatment: It usage enhances exterior scratch out-coming in best mechanical adhesive and exposes the quantities of cellulose on the strands uppermost layer. These enhance the quantity of feasible reaction areas and permits good strands humidify. The feasible response of the strands (fiber) and NaOH is acted for in equation (1) [3]:

$$\text{Fibers-OH} + \text{NaOH} \longrightarrow \text{Fibers-O-Na}^{+} + H_2O \quad \ldots\ldots (1)$$

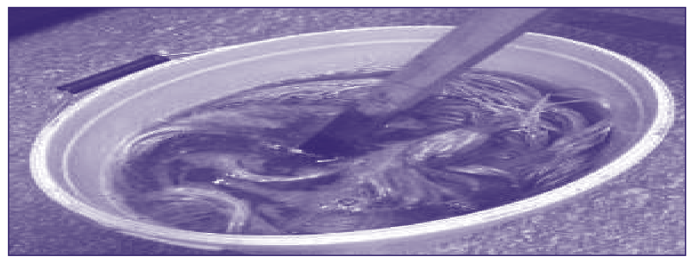
Banana strands were treated and submerged in 6% sodium hydroxide emulsion for 2 hours at ambient temperature as represent in the diagram.

Figure 3. Immersion banana strands in NaOH mixture



The substance was refrained and arid by the light of sun. Then the strands were fabricated into 4-5 mm length in the form of particulate fiber-reinforcement.

Figure 4. Chemically treated fiber



3. EXPERIMENTAL SETUP

3.1 Proximate analysis method: It involves determination of moisture, volatile matter, ash, and fixed carbon. This analysis provides data necessary for the assessment of the quality type of banana fiber. The main aim is to determine the percentage of all parameters included in this analysis for crude banana fiber. An apparatus is used such as silica crucible, weighing balance, tong, desiccators, hot air oven, and muffle furnace, etc [4]. Now, we conclude the determination of all contents present in short banana fiber and experimental procedure follow through table 2.

Table 2. Method follows for proximate analysis

S. No.	Content	Lid	Apparatus	Temperature	Time
1.	Moisture	without lid	hot air oven	110^{o}C	1 hour
2.	Volatile matter	without lid	muffle furnace	950^{o}C	7 min.
3.	Ash	without lid	muffle furnace	570^{o}C	30 min.
4.	Carbon	-	-	-	-

3.1.1 Hot air oven: This equipment gives the temperature above the environment temperature. The temperature limit by this oven is 50-250oC. These are utilized for quick vaporization of substances, quick arid, and for disinfect of particles that can be sterilized by arid temperature. The arid heat disinfects method needs a larger exposure time (1.5 to 3 hours) and maximum temperatures than wet heat disinfects [5].

Figure 5. Hot air oven apparatus (Chemistry Lab, ACERC Ajmer)

Formulas:

1. Percentage of moisture $= \frac{\text{Loss in weight}}{\text{Weight of sample taken}} \times 100$

$$= \frac{(w_2 - w_3)}{(w_2 - w_1)} \times 100$$

Where w_1 = empty crucible weight, (g)
w_2 = crucible weight + sample taken before heating, (g)
w_3 = crucible weight + sample taken after heating, (g)

3.1.2 Muffle furnace: A muffle furnace is a segment of experimentation device that can hold out the especially large temperature in the chamber, in which the piece inside is discrete from all by-products of the heating source. The temperature range of this furnace is up to 1600oC. It generally works through induction, convection by a large-temperature heating-coil in an insulating material. The enclosing material productively acts as a muffle, stopping heat from escaping [5]. Researchers in laboratories can utilize a laboratory muffle furnace for nutritional testing by identifying the quantity of fat, carbohydrate, protein, and water in a specific food. Industrial utilizes may comprise evaluating the combustion temperatures of particular materials. They are also utilized in various research potentials, for instant by chemists to evaluate what segment of a specimen is non-combustible and non-volatile (i.e. ash).

Figure 6. Muffle furnace apparatus (Chemistry Lab, ACERC Ajmer)

Formulas:

2. Percentage of VM $= \frac{\text{weight loss due to the withdrawal of volatile matter}}{\text{Weight of sample taken}} \times 100 - (\text{Percentage of moisture})$

$$= \frac{(w_5 - w_6)}{(w_5 - w_4)} \times 100 - (\text{Percentage of moisture})$$

Where w_4 = empty crucible weight, (g)
w_5 = crucible weight + sample taken before heating, (g)
w_6 = crucible weight + sample taken after heating, (g)

3. Percentage of ash $= \frac{\text{Weight of ash formed}}{\text{Weight of sample taken}} \times 100$

$$= \frac{(w_9 - w_7)}{(w_8 - w_7)} \times 100$$

Where w_7 = empty crucible weight, (g)
w_8 = crucible weight + sample taken before heating, (g)
w_9 = crucible weight + sample taken after heating, (g)

4. Percentage of fixed carbon = 100 – [% of moisture + % of volatile matter + % of ash]

3.2 Thermogravimetric analysis method: Learning on the thermal attributes of banana fiber was being carried out in the thermogravimetric analysis (TGA). The thermal exploits were evaluated using an STA 6000 (Perkin Elmer) model; in unlatched platinum, crucible accompanied by a heating rate of 20oC/min in a 40 ml/min circulates of nitrogen, in a temperature span between 15oC and 1000oC.

Figure 7. STA 6000 model testing machine (MRC Lab, MNIT Jaipur)

4. RESULTS AND DISCUSSION

4.1 Proximate analysis: In this experimental analysis, we have taken a sample of untreated and treated short banana fibers 2 grams, three samples of silica crucible weight 35.14, 35.70, and 35.37 grams. Now, we evaluate the percentage of moisture content, volatile matter, ash content, and fixed carbon by this analysis.

4.1.1 Determination of moisture content: A known amount of the short banana fiber sample taken in a dry and accurately weighed silica crucible is heated inside a hot air oven for one hour at 110oC. Cool the crucible in a desiccator and weigh it again. The loss in weight corresponds to the moisture.

Figure 8. Banana fiber sample after moisture content test in a hot air oven

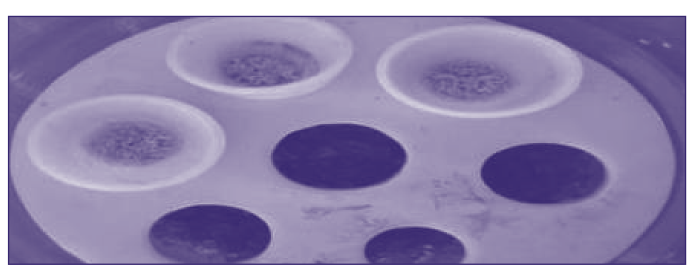


Table 3. Observations of untreated banana fibers for moisture content

S. No.	w_1	w_2	w_3	Percentage of Moisture Content	Average Percentage of Moisture Content
1.	35.14	37.14	37.00	7.00	6.67
2.	35.70	37.70	37.57	6.50	
3.	35.37	37.37	37.24	6.50	

Table 4. Observations of treated banana fibers for moisture content

S. No.	w_1	w_2	w_3	Percentage of Moisture Content	Average Percentage of Moisture Content
1.	35.14	37.14	37.03	5.50	5.00
2.	35.70	37.70	37.60	5.00	
3.	35.37	37.37	37.28	4.50	

Finally, it obtains, the average percentage of moisture content for a given sample of untreated short banana fibers is 6.67% and for treated banana fibers is 5.00%.

4.1.2 Determination of volatile matter: A known amount of sample is taken in a weighed silica crucible. The silica crucible is held in an electric muffle furnace maintained at 950oC for about 7 minutes. It is cooled and weighed. Loss in weight is represented as volatile matter. In consequence, lower the volatile matter gives best the values of the banana fibers.

Figure 9. Banana fiber sample after volatile matter test in a muffle furnace

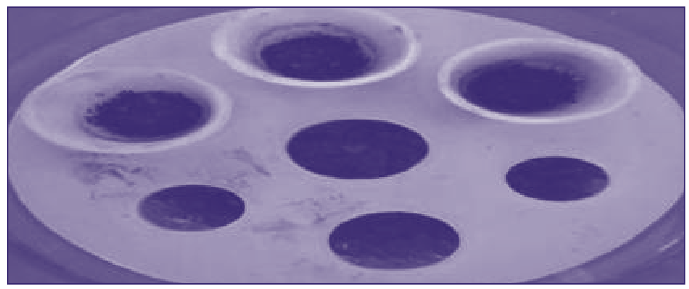


Table 5. Observations of untreated banana fibers for volatile matter

S. No.	w_4	w_5	w_6	Percentage of Volatile Matter	Average Percentage of Volatile Matter
1.	35.14	37.14	35.67	66.50	62.67
2.	35.70	37.70	36.16	70.50	
3.	35.37	37.37	36.22	51.00	

Table 6. Observations of treated banana fibers for volatile matter

S. No.	w_4	w_5	w_6	Percentage of Volatile Matter	Average Percentage of Volatile Matter
1.	35.14	37.14	35.80	67.00	63.67
2.	35.70	37.70	36.27	71.50	
3.	35.37	37.37	36.32	52.50	

Finally, it obtains, the average percentage of volatile matter for a given sample of untreated banana fibers are 62.67%, and treated banana is 63.67%.

4.1.3 Determination of ash content: A known quantity of dried banana fiber sample is burned in an open crucible at 570oC for about 30 minutes in a muffle furnace until a stationary weight of residue is gained. The remaining substance is reported as ash content on the basis of percentage.

Figure 10. Banana fiber sample after ash content test in a muffle furnace

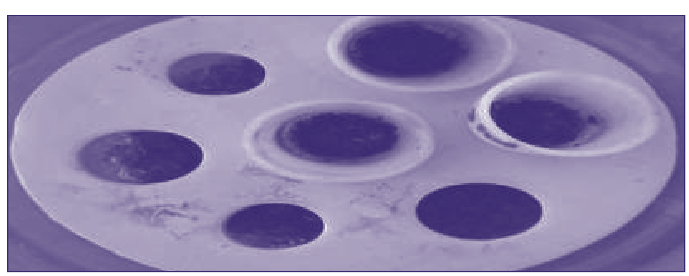


Table 7. Observations of untreated banana fibers for ash content

S. No.	w_7	w_8	w_9	Percentage of Ash Content	Average Percentage of Ash Content
1.	35.14	37.14	35.37	11.50	13.33
2.	35.70	37.70	36.00	15.00	
3.	35.37	37.37	35.64	13.50	

Table 8. Observations of treated banana fibers for ash content

S. No.	w_7	w_8	w_9	Percentage of Ash Content	Average Percentage of Ash Content
1.	35.14	37.14	35.48	17.00	18.83
2.	35.70	37.70	36.10	20.00	
3.	35.37	37.37	35.76	19.50	

Finally, it obtains, the average percentage of ash content for a given sample of untreated banana fibers is 13.33%, and treated banana fibers are 18.83%.

4.1.4 Determination of fixed carbon: It represents the quantity of carbon in short banana fiber. The maximum percentage of fixed carbon, the larger is the calorific value. Thus higher percentage of fixed carbon is desirable.

Calculation of untreated banana fibers for fixed carbon:
1. 100 – [7.0 + 66.50 + 11.50] = 15%
2. 100 – [6.5 + 70.50 + 15.00] = 8%
3. 100 – [6.5 + 51.00 + 13.50] = 29%

Calculation of treated banana fibers for fixed carbon:
1. 100 – [5.5 + 67.00 + 17.00] = 10.50%
2. 100 – [5.0 + 71.50 + 20.00] = 3.50%
3. 100 – [4.5 + 52.50 + 19.50] = 23.50%

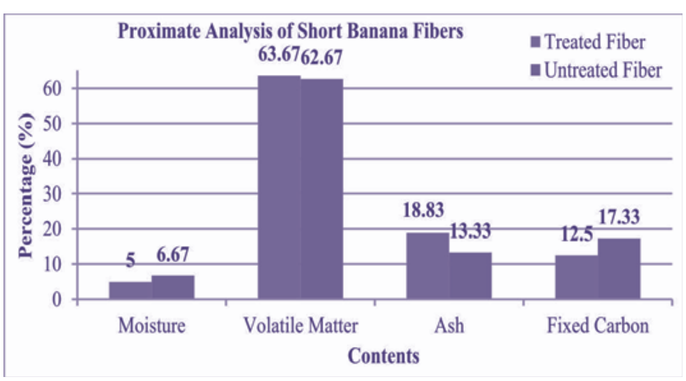
Finally it obtains, the average percentage of fixed carbon for a given sample of untreated banana fibers are 17.33% and for treated banana fibers are 12.50%. Now, we conclude the all average value of determining by the proximate analysis. The experimental data is shown below in the table.

Table 9. Contents present in short banana fibers

S. No.	Average Percentage of Content	Untreated Banana Fibers	Treated Banana Fibers
1.	Moisture (wt %)	6.67	5.00
2.	Volatile matter (wt %)	62.67	63.67
3.	Ash (wt %)	13.33	18.83
4.	Fixed carbon (wt %)	17.33	12.50

It can be seen from the above table 9 that the value of percentage volatile matter is greater for treated short banana fibers than the untreated short banana fibers.

Figure 11. Quantitative analysis of the short banana fibers



In this analysis, the contents present in short banana fiber for treated fibers volatile matter and ash content is more than that of untreated fibers. In untreated fibers, moisture and fixed carbon are more than that of treated fibers.

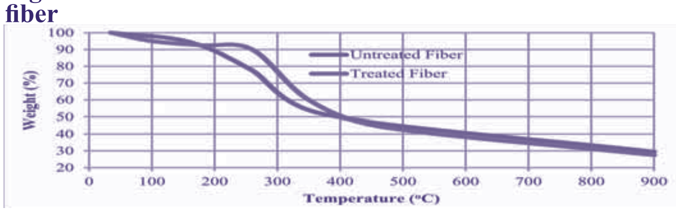
4.2 Thermogravimetric analysis experiment: It can recognize that the curve in the figure shows an unalike functioning, with four principal weight loss steps for the untreated fiber and two principal weight loss steps for the treated banana fibers. In the first phase (114oC and 72oC for untreated fibers and treated fibers, separately), a weight loss associated with desorption of liquid of the polysaccharide shape was perceived. Even if fibers have become dry before the analysis, the entire destruction of water is completely tough because of their hydrophilic nature. For example, liquid also exists as shaped bound liquid molecules. For the untreated fibers, the second phase (216oC) can be characterized by the disintegration of the hemicellulose contentment. The third one (322oC) is characterized by the residual lignin decomposition reaction degradation, and the fourth one (394oC) is caused by the breakdown of the protolignin bonds. For the treated fibers, the disintegration of cellulose and lignin are being associated with the second and main step at 378oC.

Table 10. Thermogravimetric analysis results

S. No.	Sample	ΔT (ºC)	T_{peak} (ºC)	T_{onset} (ºC)	Mass Loss (%)	Residue (%)
1.	Untreated banana fiber	35-160 160-260 260-375 375-900	114 216 322 394	153	5.48 16.94 26.14 21.96	29.47
2.	Treated banana fiber	35-180 180-900	72 378	200	6.94 65.56	27.50

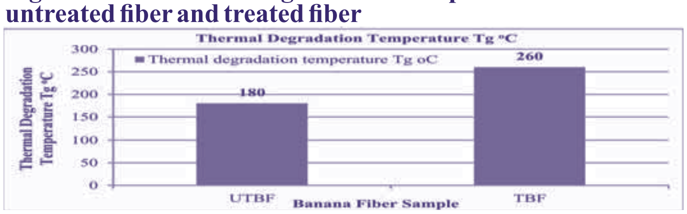
Examine the value in table 10, it is feasible to perceive that the vital weight loss for the untreated banana fibers happened across the third step (26.14%), and the weight loss takes place normally in the second step between 180oC and 900oC for the treated banana fibers. To evaluate the thermal constancy and the effect of treating on the fiber's thermal properties was being carried out the thermogravimetric analysis. The thermogravimetric analysis curve is representing in figure 12.

Figure 12. TGA curves of banana untreated fiber and treated fiber



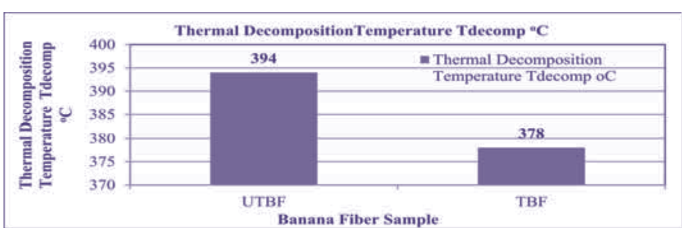
Even if the cleaning could not separate all of the unstructured composition present in the fiber, it enhanced the temperature at which the deterioration of the fiber occurs; consequently, there was a refinement in the fiber's thermal reliability. The thermal degradation region of untreated and treated banana strand is 180oC and 260oC, which is representing through the bar graph in figure 13.

Figure 13. Thermal degradation temperature of banana untreated fiber and treated fiber



The thermal decomposition region of untreated and treated banana fiber is 394oC and 374oC, which is representing through the bar graph in figure 14.

Figure 14. Thermal decomposition temperature of banana untreated fiber and treated fiber



CONCLUSION

Banana strands are gained from the banana herbs that are the trash outcome of banana cultivation. There is an increase in the value of volatile matter of short banana fiber in proximate analysis while the standard fiber properties like cellulose 63-64%, hemicellulose 19%, lignin 5%, moisture content 10-11%, density 1.350 g/cc, tensile strength 550+6.8 MPa. There is a decrease in the level of impurity and a decrease in crystallinity compared to the level of impurity of treated banana fibers obtained from banana peel. Also, later on, untreating the fiber had higher reliability in temperatures up to 375oC and high roughness on its outermost layers.

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REFERENCES

[1] *Marcos Vinicius Fonseca Ferreira and Sergio Neves Monteiro, "Thermogravimetric Characterization of Polyester Matrix Composites Reinforced with Eucalyptus Fibers", Journals of Materials Research and Technology, vol. 6, no. 4, 2017.*

[2] *KettyBilba, Marie-AngeArsene and Alex Ouensanga, "Study of Banana and Coconut Fiber Botanical Composition: Thermal Degradation and Textural Observations", Bioresource Technology: Elsevier, pp. 58–68, 2007.*

[3] *U.P. Onochie, A.I. Obanor, S.A. Aliu and O.O. Ighodaro, "Proximate and Ultimate Analysis of Fuel pellets from Oil Palm residues", Nigerian Journal of Technology (NIJOTECH), vol. 36, no. 3, pp. 987-990, 2017.*

[4] *Sanjay Sharma, "Engineering Chemistry", 1st ed. Laxmi Publication, 2016. [E-book]*

[5] *Farid R. Abadi, "Design of a Simple Muffle Furnace for Temperature Optimization in Ash Content Analysis", Journal neutrino: Journal Fisika Dan Aplikasinya, vol. 10, no.2, pp. 30-39, 2018.*

[6] *Pabir Basu, "Biomass Gasification and pyrolysis", Biomass Characteristics: Science Direct, pp. 50-55, 2010.*

[7] *N. Rao Cheepurupalli and B. Anuradha, "Proximate and Ultimate Characterization of Coal Samples from Southwestern Part of Ethiopia", International Journal of Engineering and Advanced Technology (IJEAT), vol. 9, no. 2, 2019.*

[8] *Nilza G. Justiz-smith, G. Junior Virgo and Vernon E. Buchanan, "Potential of Jamaican Banana: Coconut Coir and Bagasse Fibers as Composite Materials", Journal of MaterialCharacterization: Elsevier, pp.1273-1278, 2007.*

[9] *Ravi Bhatnagar, Gourav Gupta, and Sachin Yadav, "A Review on Composition and Properties of Banana Fibers", International Journal of Scientific and Engineering Research, vol. 6, no. 5, 2015.*

[10] *Soma Gorai, "Utilization of Fly ash for sustainable environment management", Journal of Materials and Environmental Sciences, vol. 9, no. 2, 2018.*

[11] *M.Z. Hassan, S.M. Sapuan and Z.A. Rasid, "Thermal Degradation and Mechanical Behavior of Banana Pseudo Stem Reinforced Composites", International Journal of Recent Technology and Engineering (IJRTE), vol. 8, no. 4, 2019.*

[12] *Samrat M. and Raul F., "Banana Fibers – Variability and Fracture Behavior", Journal of Engineered Fibers and Fabrics, vol. 3, no. 2, 2008.*

[13] *Sanjay Sharma, "Engineering Chemistry", 1st ed. Laxmi Publication, 2016. [E-book]*

[14] *Engr. Ojukwu Martins chubuike, Chukwunyelu Christian Ebele, Engr. Ilo Fidelis Ifeanyi, Ekwueme Solomon Okwuchukwu, and Orizu Eziafa Festus, "Study on Chemical Treatments of Jute Fiber for Application in Natural Fiber Reinforced Composites (NFRPC)", International Journal of Advanced Engineering Research and Science (IJAERS), vol. 4, no. 2, 2017.*

[15] *Anu Gupta and Ajit Kumar, "Chemical Properties of Natural Fiber Composites and Mechanisms of Chemical Modifications", Asian Journal of Chemistry, vol. 24, no. 4, 2012.*