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Tensile Characterization of Pre-harvest Treated Pineapple Leaf Fibre

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Authors' contributions

This work was carried out in collaboration between both authors. Author HU designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author GEO managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

This study was undertaken to evaluate the effect of field practice on the tensile properties of pineapple leaf fibre (PAFL). The pineapple leaves were treated in the field with calcium nitrate ($Ca(NO_3)_2$) at four concentrations (0 mg/l, 100 mg/l, 200 mg/l and 300 mg/l). All the treatments were applied through foliar application, twice monthly, for duration of five months. The pineapple leaves were harvested after five months of the treatment application, and their fibre extracted through the retting method. In addition, the cellulose content of the PALF was determined according to approved method. The extracted fibre was subjected to tensile test, using ASTM International approved methods. Results obtained from the tensile test revealed that the pre-harvested treatment had significant ($p \leq 0.5$) effect on the tensile properties of the PALF. The tensile strength increased from 583.67 MPa to 880.83 MPa; while the Young's modulus increased from 23.77 GPa to 28.23 GPa, as the treatment concentration increased from 0 mg/l to 300 mg/l. Likewise, the tensile elongation decreased from 3.13 mm to 1.83 mm, as the treatment concentration increased from 0 mg/l to 300 mg/l. In terms of the cellulose content, the study revealed that the cellulose content of the fibre increased significantly ($p \leq 0.05$) with increased in the treatment concentration. At the concentration of 0 mg/l, the PAFL had cellulose content of 63.6%, which increased linearly to 77% at the concentration of 300 mg/l. From these results, it can

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be seen that field practice greatly increased the potential of PALF in composites production and other industrial applications.

Keywords: Calcium nitrate; field practices; PALF; tensile strength; tensile elongation.

1. INTRODUCTION

Pineapple (*Ananas comosus*) which belongs to the *Bromeliaceae* family is a perennial plant, and one of the essential fruits, which is consumed either as a fresh or processed product. Pineapple is widely cultivated in many parts of the world, as it is able to tolerate wide range of soil nutrients and soil pH, but it is sensitive to waterlogged area [1]. About 27.4 million tons of pineapple fruits were produced globally in 2017; out of which Nigeria harvested about 1.7 million tons of pineapple fruits [2]. Pineapple fruits and leaves have a lot of medicinal, nutritional and industrial applications. According to the United States Department of Agriculture (USDA, pineapple fruits contains a lot of vitamins, minerals and antioxidants [3]. The fibre extracted from the leaves contains a high proportion of cellulose and better tensile properties, making it one the best plant fibre compared to other plants' fibres [4]; thus, it can be confidently used in composites production [5].

The industrial application of plant fibres are increasingly recently, mostly in the composite and textile industries. Plants fibres are widely available, cost-effective, biodegradable, flexibility, recyclable, light weight, and non-carcinogenic [6,7]. They are obtained either from plants' leaves, stems, stalks, fruits, canes, seeds or grains. Leaf fibres are obtained from crops like pineapple, Abaca, etc.; stem fibres are obtained from crop like okra; cane fibres are obtained from plant like bamboo; fruit fibres are gotten from fruits like coconut; while stalk fibres are obtained from crop like wheat [8]. Due to their environmental friendly nature, plants fibres are widely used to replaced synthetic fibres in composite industries, fabric industries (decoration and yarn), construction industry, sports industry, etc. [7,9]. One major advantage of plants fibres is that, its production and utilization helps in agricultural waste management. Most of the plants' parts from where the fibres are obtained are considered as waste in crop production. For instance, the pineapple leaves and okra stem are considered as waste (thrash), after harvesting the pineapple fruit and okra pods. According to FAO [10], plants fibres engineering properties are greatly affected by the soil fertility, harvesting period, environmental temperature, harvesting technique, and humidity.

Naturally plants fibres have weaker mechanical properties and high moisture absorption, when compared with their synthetic fibres counterparts. These limitations can be overcome by chemically modifying (post-harvest treatment) the fibres, before their utilization. Several researchers have chemically modified plants fibres, achieving fibres with superior mechanical properties. Siva and Paul [11] investigated the effect of sodium hydroxide (NaOH) treatment on the tensile strength of pineapple leaf fibre (PALF), and they reported that the tensile strength of PALF treated with 10% NaOH increased from 214.16 MPa to 283.82 MPa, making is a potential composite reinforcement material. Alkaline modification of kenaf fibres was observed to regenerate the cellulose content of the fibres, and dissolved microscopic cracks on the fibres surfaces, hence, increasing their mechanical properties [12]. Alkaline modification of flax fibre improved the tensile strength and Young's modulus of the epoxy composite produced from it by about 30% [13]. Jacob et al. [14] in their experimental research observed that, alkaline treatment of fibres greatly improved their mechanical properties. Despite the numerous advantages of chemical post-harvest treatment of plants fibres, it still has some drawbacks. It was observed that high chemical concentration or prolongs treatment duration (or both factors) will lead to delignification of fibres; thereby, lowing their tensile and flexural properties [15].

Recently, there is a growing trend on pre-harvest treatments of plants, to improve their engineering properties of their tissues; if the limitations of the post-harvest treatments can be overcome. These pre-harvests treatments are mainly in the form of foliar application or incorporating the treatment into the soil, during the growing period of the plants. Citing Li *et al*. [16], calcium application helped to increase the rupture resistance of litchi (*Litchi chinensis*) fruit's tissues; when compared the results of the fruits pre-harvest treated with calcium solution, with the untreated fruits from the control unit. Likewise, the mechanical strength of litchi fruits' skin was increased by the field practices involving the application of calcium chloride and borax solution [17]. Edafeadhe [18] observed that the tensile properties of fibre extracted from okra planted pre-harvest treated with calcium nitrate were superior, compared to the untreated okra plants fibre. Furthermore, Sams [19] reported that pre-harvest application of calcium solution helped to increase the firmness of plants' tissues. Field practices have the ability of increasing cellulose and calcium contents; thereby, increasing the tensile, hardness and flexural properties of their fibres [20]. Although the application of calcium nitrate ($Ca(NO_3)_2$) as pre-harvest treatment for many crops have been investigated, reports on pre-harvest application of $Ca(NO_3)_2$ on pineapple leaves, to increase its fibre mechanical properties are limited. Therefore, this study investigated the effects of $Ca(NO_3)_2$ field treatment on the tensile and biochemical properties of pineapple leaf fibre.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Pineapple

The pineapple plants were grown in a private orchard at Ozoro, Delta State, Nigeria. The plants were cultivated at a spacing of 3 × m distance, in organic farming method.

2.1.2 Experimental design

The experiment consisted of four treatments (including the control). The treatments were: (i) 0 mg/l $Ca(NO_3)_2$ or distil water, which was taken as the control unit; (ii) 100 mg/l $Ca(NO_3)_2$; (iii) 200 mg/l $Ca(NO_3)_2$; (iv) 300 mg/l $Ca(NO_3)_2$. Pineapple plants were sprayed with knapsack sprayer, until the each plant was completely wet. The treated was applied twice monthly. Application of the treatment started from when the pineapple plants were three months old, and continued until they were cut for laboratory analysis as the age of eight (8) months. Each of the treatment was triplicated, in a randomized complete block design.

2.2 Methods

2.2.1 Fibre extraction

The retting method was used to extract the fibre from the pineapple leaves. During the process, the leaves were soaked inside muddy water for 10 days, before the fibre was removed from the leaves, The fibre was then washed with water to remove all the pulp, and then sun-dried for 5 days at ambient environmental conditions

2.2.2 Tensile properties test

The tensile properties of the PAFL were measured using the Universal Testing Machine (Testometric: model, M500 100AT). The PALF was cut to 15 mm length samples, which were then tested in accordance to ASTM C1557 (2003) procedures, as shown in Fig. 1. During the test, a sample which was clapped to the jaws of the machine was pulled at a slow speed of 3 mm/min, until the fibresnapped [21]. As the test progresses, a force-elongation curve is plotted by the machine microprocessor, in relationship to the fibre response to the tension force (Fig. 2). At the end of each test, the tensile strength, Young's and the tensile elongation were calculated by the microprocessor of the machine, and displayed on the screen attached to the machine. Twelve samples were tested from each experimental plot.

Fig. 1. PALF undergoing tensile testing

2.2.3 Biochemical analysis

The cellulose content of the PALF was determined in accordance to the procedures given by [22]. Three samples were tested from experimental plot. All the laboratory tests were carried out at ambient laboratory conditions (temp 28±5^{0}C; RH 85±4%).

2.3 Statistical Analysis

All raw results gotten from this study will be subjected to analysis of variance (ANOVA) using SPSS (version 20.0, SPSS Inc, Chicago, IL). Then the means will be separated and compared using Duncan's Multiple Range Tests (DMRT) at 95% confidence level.

3. RESULTS AND DISCUSSION

3.1 Biochemical Properties

3.1.1 Cellulose content

The cellulose content of the PALF given in (Table 1) showed that $Ca(NO_3)_2$ treatment had significant effect on the cellulose content of the leaves. The study revealed that the control (T1) fibre developed the lowest cellulose, while the pineapple plants treated with 300 mg/l $Ca(NO_3)_2$ developed the highest cellulose, within the experimental period. Regression equation presented in (Equation 1) showed that there is strong relationship ($R^2 \geq 9.0$) between the calcium pre-harvest treatment and the cellulose content of the fibre. According to Dumas et al. [23], field practice is one of the major factors that determined the concentration of biochemical properties of agricultural products.

$$y = 4.399x + 58.17 \qquad (R^2 = 0.945) \qquad (1)$$

Where:
y = cellulose content
x = $Ca(NO_3)_2$ concentration (mg/l)

3.2 Tensile Properties

The ANOVA results presented in (Table 2) showed that, pre-harvest treatment of the PALF with $Ca(NO_3)_2$ had significant effect on its tensile properties (tensile strength, Young's modulus and tensile elongation). The tensile strength shown in (Fig. 3) portrayed that the tensile strength of the PALF increased linearly, with increased in the $Ca(NO_3)_2$ concentration. Treatment 1 (control) PALF had the lowest tensile strength (583.67 MPa), while the T4 PALF developed the highest tensile strength (880.83 MPa). Linear regression model given in (Equation 2), reveals that there is a good relationship (R^2= 0.850), between the $Ca(NO_3)_2$ concentration and the tensile strength of the fibre. Increment in the tensile strength observed in the pre-harvest treated PALF, could be attributed to the superior cellulose content of the treated fibre, as shown in (Table 1). High cellulose concentration in plant's fibre, normally helps to increase its tensile and flexural properties [24,25].

The study revealed (Fig. 4) that the PALF Young's modulus increased significantly ($p \leq 0.05$), with pre-harvest treatment. The fibre harvested from the control unit (T1) recorded the least Young's modulus (23.77 GPa); while the fibre harvested from the T4 had the highest Young's modulus (28.23 GPa). Although T4 fibre Young's modulus was superior to the T3 fibre, no significant difference existed between the Young's modulus of the two treatments fibre, as shown in (Fig. 2). Just as in the case of the tensile strength, these results further affirmed that pre-harvest amendment greatly influence the mechanical properties of plant's tissues. Mechanical properties of plant fibres are greatly influenced by the plant variety, maturity age, extraction technique, etc. [26].

The tensile elongation presented in (Fig. 5) showed that, the deformation of the fibre during the tension decreased significantly, as the treatment concentration increased from 0 mg/l to 300 mg/l. At T1, the PALF experienced elongation of 3.13 mm, which declined linearly T4, where the fibre experienced an elongation of 1.83 mm. This showed that the fibre becomes stiffer with an increment in the treatment concentration, which may be attributed calcium content of the calcium nitrate solution. According to Li et al. [27], calcium treatment helps to increase the firmness of plants' tissues; hence, improving the breaking strength of herbaceous peony (*Paeonia Lactiflora* Pall) stems. This study has revealed that pineapple leaves tensile properties, can be successfully increased through pre-harvest treatment; similar to previous studies [28,29] which were based on post-harvest chemical modifications of PALF. The superior tensile properties displayed by the pre-harvest treated fibre, increased its reinforcement potential in composites production for various applications.

$$y = 95.54x + 450.1 \qquad (R^2 = 0.850) \qquad (2)$$

Where:
y = tensile strength (MPa)
x = $Ca(NO_3)_2$ concentration (mg/l)

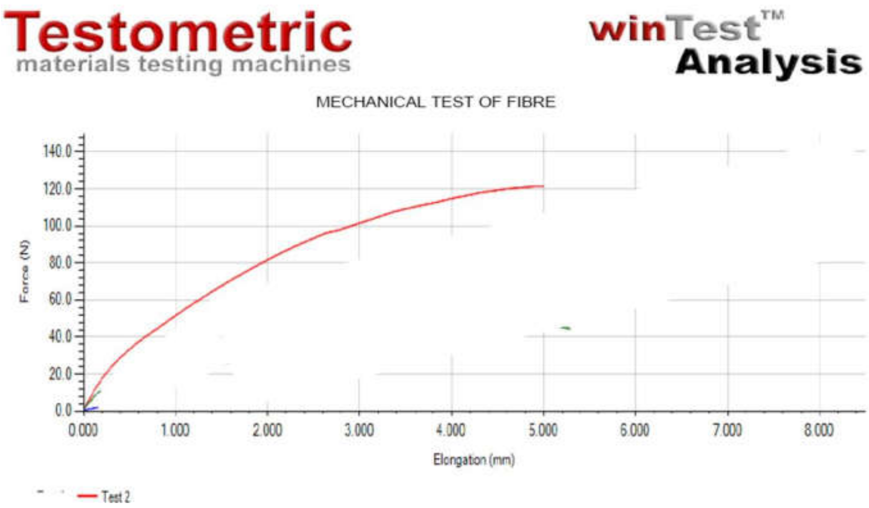

Fig. 2. A force-elongation curve

Table 1. PAFL cellulose content

Treatment	Cellulose (%)
T1	63.67[a]±0.88
T2	66.00[ab]±1.15
T3	70.00[b]±0.58
T4	77.00[c]±2.08
Mean	**69.17±1.62**
Duncan (p ≤0.05)	**4.39E-04***

*Mean± standard error; n=3; mean separation within columns by Duncan's multiple range tests (DMRT); * significant at p ≤ 0.05*

Table 2. ANOVA results of the effect of treatment on PALF tensile properties

Parameters	Df	Mean square	F Stat	P value
Tensile Strength	3	214679.42	339.00	2.05E-30*
Young's Modulus	3	48.77	26.85	5.02E-10*
Elongation at break	3	3.64	93.34	4.21E-19*

** = significant (Duncan p ≤0.05)*

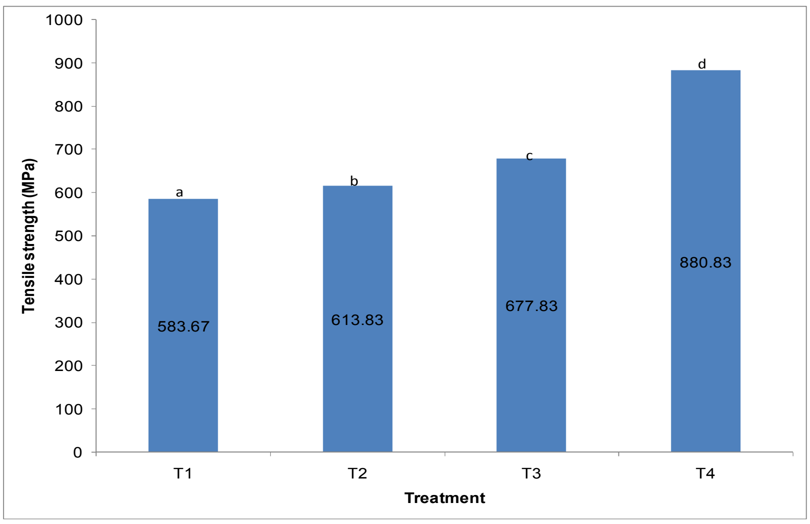

Fig. 3. Tensile strength of pre-harvest treated PALF
Columns with the same common letters means that they are not significant different at (p ≤0.05)

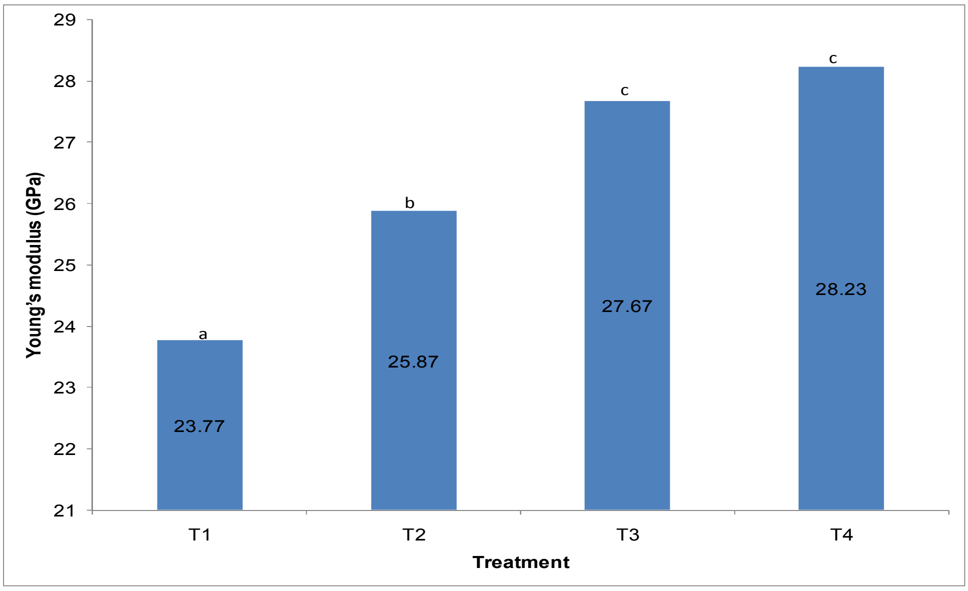

Fig. 4. Young's modulus of pre-harvest treated PALF

Columns with the same common letters means that they are not significant different at (p ≤0.05)

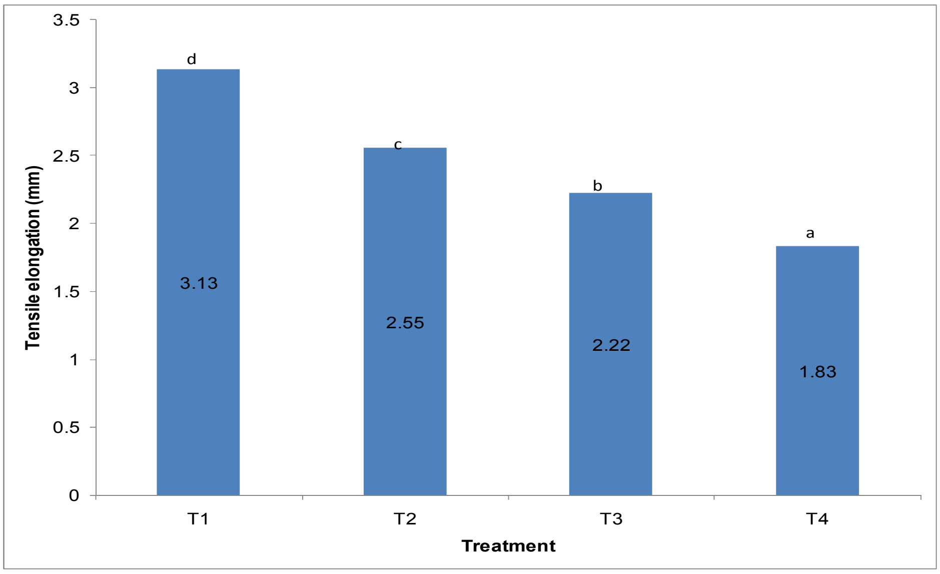

Fig. 5. Tensile elongation of pre-harvest treated PALF

Columns with the same common letters means that they are not significant different at (p ≤0.05)

4. CONCLUSION

This study evaluated the effect of field practices (pre-harvest treatment) on the tensile properties of pineapple leaf fibre. The pineapple leaves were subjected to four treatment plans (0 mg/l, 100 mg/l, 200 mg/l and 300 mg/l) of calcium nitrate. Fibre was extracted from the leaves through retting method, and tested according to ASTM International method. It was observed from the results that the pre-harvest treatment, significantly (p ≤0.05) increased the Tensile strength and Young's modulus of the PAFL, but decreased the tensile elongation. Control (T1) fibre had tensile strength and Young's modulus of 583.67 MPa and 23. 77 GPa respectively; while the leaves pre-harvest treated 300 mg/l $Ca(NO_3)_2$ (T4) recorded a tensile strength and Young's modulus of 880.83 MPa and 28.23 GPa respectively. Beside the superior tensile properties displayed by the treated PALF; the treated fibre recorded a higher cellulose content compared to the control fibre. This study has shown that pre-harvest treatment of PALF will increased its utilization in composites production, and other industrial applications.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Food and Agriculture Organization - FAO. Pineapple Production. Available:http://www.fao.org/land-water/databases-and-software/crop-information/pineapple/en/. Retrieved on January, 2018
2. FAOSTAT. Pineapple production. Available:http://www.fao.org/faostat/en/#data/QC Retrieved on March, 2019
3. United States Department of Agriculture - USDA. Pineapple nutrients. Available:https://ndb.nal.usda.gov/ndb/search/list?qlookup=09266. Retrieved January, 2018
4. Reddy N, Yang Y. Biofibers from agricultural by products for industry applications. Trends Biotechnol. 2005;23: 22–27.
5. Mishra S, Misra M, Tripathy SS, Nayak SK, Mohanty AK. Potentiality of pineapple leaf fibre as reinforcement in PALF-polyester composite: Surface modification and mechanical performance. Journal of Reinforced Plastics and Composites. 2001; 20(4):321–334.
6. Herrera-Franco PJ, Valadez-Gonz´alez A. A study of the mechanical properties of short natural-fiber reinforced composites. Composites Part B: Engineering. 2005; 36(8):597–608.
7. Asim M, Abdan K, Jawaid M, Nasir M, Dashtizadeh Z, Ishak MR, Hoque ME. A review on pineapple leaves fibre and its composites. International Journal of Polymer Science. 2015;1-16.
8. Bongarde VDS. Review on natural fiber reinforcement polymer composites. International Journal of Engineering Science and Innovative Technology. 2014; 3(2):431–436.
9. Drzal M, Mohanty LT, Misra AK. Bio-composite materials as alternatives to petroleum-based composites for automotive applications. Magnesium. 2001;40:1–3.
10. FAO. Application of natural fibre composites in the development of rural societies. Rome; 2003. Available:http://www.fao.org/3/ad416e/ad416e06.htm. Retrieved on March, 2018
11. Siva N, Paul JJ. Fabrication and experimental analysis of pineapple leaf fiber based composite material. Journal of Chemical and Pharmaceutical Sciences. 2015;243-24.
12. Keshk S, Suwinarti W, Sameshima K. Physicochemical characterization of different treatment sequences on kenaf bast fibre. Carbohydr Polym. 2006;65(2): 202–206.
13. Van de Weyenberg I, Ivens J, De Coster A, Kino B, Baetens E, Vepoes I. Influence of processing and chemical treatment of flax fibres on their composites. Composites Science and Technology. 2003;63:1241-1246
14. Jacob M, Thomas S, Varughese KT. Mechanical properties of sisal/oil palm hybrid fiber reinforced natural rubber composites. Composites Science and Technology. 2004;64(7-8):955-965.
15. Mishra S, Mohanty AK, Drzal LT, Misra M, Parija S, Nayak SK, Tripathy SS. Studies on mechanical performance of biofibre/glass reinforced polyester hybrid composites. Composites Science and Technology. 2003;63(10):1377–1385.
16. Li JG, Huang HB, Gao FF, Huang XM, Wang HC. An overview of litchi fruit cracking. Acta Hortic. 2001;558:205-208.
17. Haq I, Rab A. Foliar application of calcium chloride and borax affects the fruit skin strength and cracking incidence in litchi (*Litchi chinensis* Sonn.) cultivars. African Journal of Biotechnology. 2012;11(10): 2445-2453.
18. Edafeadhe GOI, Uguru H. Effect of pre-harvest treatment on the tensile and biochemical properties of okra (*Abelmoschus Esculentus* L) fibre. Direct Research Journal of Chemistry and Material Science. 2020;7(1):7-11.

19. Sams CE. Preharvest factors affecting postharvest texture. Postharvest Biology and Technology. 1999;15:249–254.
20. Edafeadhe GOI, Agbi GG, Uguru H. Effect of calcium nitrate application on the structural behaviours of okra (cv.Kirikou) fibre reinforced epoxy composite. Direct Research Journal of Engineering and Information Technology. 2020;7(2):69-74.
21. Uguru H, Uyeri C. Effect of vine section on the tensile properties of fluted pumpkin vine. Direct Research Journal of Engineering and Information Technology. 2018;5(5):32-35.
22. Gaines TP, Mitchell GA. Chemical Methods for Soil and Plant Analysis. Univ. of Georgia, Costal Plain Exp Stn Agron Handbook no.1; 1979.
23. Dumas Y, Dadomo M, Lucca G, Grolier P, Di Luca G. Effects of environmental factors and agricultural techniques on antioxidant content of tomatoes. Journal of the Science of Food and Agriculture. 2003;83: 369-382.
24. Fakirov DBS. Wood Fibre Thermoplastic Composite: Processing Properties and Future Developments. Hanser, Munich, Germany; 2007.
25. Saheb DN, Jog JP. Natural fiber polymer composites: a review. Advances n Polymer Technology. 1999;18(4):351–363.
26. Rowell RM, Han JS, Rowell JS. Characterization and factors effecting fiber properties. Natural Polymers and Agrofibers Based Composites. 2000;115–134.
27. Li C, Tao J, Zhao D, You C, Ge J. Effect of calcium sprays on mechanical strength and cell wall fractions of herbaceous peony (*paeonia lactiflora* pall.) inflorescence stems.int. International Journal of Molecular Sciences. 2012;13:4704-4713.
28. Siregar JP, Sapuan MS, Rahman MZA, Zaman HMDK. The effect of alkali treatment on the mechanical properties of short pineapple leaf fbre (PALF) reinforced high impact polystyrene (HIPS) composites. Journal of Food, Agriculture and Environment (JFAE). 2010;8(2):1103–1108.
29. Arib RMN, Sapuan SM, Ahmad MMHM, Paridah MT, Zaman HMDK. Mechanical properties of pineapple leaf fibre reinforced polypropylene composites. Materials and Corrosion. 2006;27(5):391–396.

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