Direct RESEARCH JOURNALS

Direct Research Journal of Chemistry and Material Science
Vol.7 (1), pp. 7-11, March 2020
ISSN 2354-4163
DOI: https://doi.org/10.26765/DRJCMS12129868
Article Number: DRJCMS12129868

https://directresearchpublisher.org/drjcm/

Full Length Research Paper

Effect of Pre-Harvest Treatment on the Tensile and Biochemical Properties of Okra (*Abelmoschus Esculentus* L) Fibre

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Received 12 February 2020; Accepted 20 March, 2020

ABSTRACT: The improvement in the mechanical properties of plant fibres, to enhance high quality composites production, is still a great concern to the scientific world. This study was done to evaluate the effect of pre-harvest treatment on the tensile properties of okra (cv.kirikou) fibre. The okra plants were pre-harvest treated with five concentrations (0 mg/l, 100 mg/l, 200 mg/l, 300 mg/l and 400 mg/l) of calcium nitrate. All the treated okra plants were harvested at 80 days after planting, and their fibre extracted through the retting method. The tensile properties of the fibre, obtained from each treatment were determined using the ASTM C1557:03 recommended procedures. In addition, the calcium and cellulose content of the fibres were determined using approved standard methods. Results obtained revealed that the pre-harvest treatment significantly ($p \leq 0.05$) affected the tensile properties, by increasing the tensile strength and Young's modulus. The tensile strength increased from 214.8 MPa to 311 MPa, while Young's modulus increased from 5.84 GPa to 10.76 GPa; as the treatment concentration increased from 0 mg/l to 400 mg/l. Furthermore, the results have shown that pre-harvest treatment significantly increased the calcium and cellulose content of the fibre. The fibre calcium content increased from content 6.37 mg/100g DW to 11.40 mg/100g DW; while the cellulose concentration increased from 54% to 78.33%, as the treatment concentration increased from 0 mg/l to 400 mg/l. This study had shown that okra fibre can be improved b pre-harvest treatment. This study is not only beneficial to the fibre/composite industry but to plant breeders, as calcium is one of the essential nutrients required by plants.

Keywords: Biochemical, calcium nitrate, fibre, okra, pre-harvest, tensile properties

INTRODUCTION

Natural fibres are classified based on their source; which are either plant fibre or animal fibre (Srinivasababu, 2015). Thakur et al. (2014) stated that some unique properties of plants fibres are: biodegradability, recyclability, availability, low density, good thermal properties, non-poisonous to human beings. Therefore, they are widely utilized in the automobile and aircraft industries in the production of doors, panels, truss members, roofs, etc. (Huda *et al*., 2007; Cristaldi *et al*., 2010). The past 30 years had witness a surge in the demand of plants fibres as reinforcement materials in composite production (Mwaikambo and Ansell, 2002).

The applications of plant fibres in composites production is highly dependent their morphology, biochemical composition, physical characteristics and mechanical properties (Brígida et al., 2010). These properties (morphology, biochemical composition, physical characteristics and mechanical properties) of the plant's fibre can be positively altered, through chemical modifications (treatments). According to Bouatay *et al*. (2014) and Brígida et al. (2010), chemical modification of plant's fibre helped to improve its wettability, modified its microstructure and surface topography; which happen through the elimination of lignins, hemicelluloses, pectins, etc. from the fibre.

Several authors have studied the effect of post-harvest treatment on the engineering properties of plants fibres. Some of the post-harvest chemical modifications, applied to plants' fibres to improve their engineering properties include; alkali treatment with sodium hydroxide, bleaching with sodium hypochlorite, treatment with ethylene diaminetetra-acetic acid, etc. (Msahli *et al*., 2006). According to Mwaikambo and Ansell (2002), treating hemp, jute, sisal and kapok fibres with 6% sodium hydroxide (NaOH) solution, improve their mechanical properties by cleaning the fibres bundle surfaces. Similarly, Mir et al. (2012) reported that chemical treatment of coir fibre, with chromium sulfate ($CrSO_4$) solution increased its tensile strength from 50.4 MPa to 84.8 MPa. In contrast, De Rosa *et al*. (2010) reported that chemical treatment of okra fibre resulted in decline (from 233.8 ± 126.4 MPa to 52.6 ± 23.0 MPa) in its tensile strength. Post-harvest fibre treatment has some severe limitations, as high treatment concentration or prolong treatment duration will lead to excessive delignification of fibres; thereby, negatively affecting their tensile properties (Mishra *et al*., 2013). Bledzki et al. (2008) stated that high concentration of mineral acids or salts can cause hydrolysis of the plant's fibre cellulose content; thereby damaging the fiber structure.

Okra (*Abelmoschus esculentus* L.) is one of the most cultivated crops most Africa and Asia countries. According to Food and Agricultural Organization (FAO), about 10 million tons of okra produced globally in 2018, and Nigeria accounted for 2.04 million tons of the total world production (FAOSTAT, 2018). Okra fibre is extracted from the bark of the okra plant, and it is widely used in composites production, due to its excellent physico-mechanical properties (De Rosa *et al*., 2010). Okra fibre, just like other plants fibres, displayed variability in its mechanical properties (tensile strength and Young's modulus). Okra fibre is utilized in many industrial applications. Just like other plant fibre, many post-harvest treatments have been carried out on it to improve its engineering properties. But there is no recorded literature or work on the pre-harvest treatment of okra fibre, to improve its engineering properties. In this study, some tensile properties (tensile strength and Young's modulus) of okra (cv. Kirikou) fibre pre-harvest treated with calcium nitrate ($Ca(NO_3)_2$ at various concentrations (0 mg/l, 100 mg/l, 200 mg/l 300 mg/l and 400 mg/l) was investigated.

MATERIALS AND METHODS

Okra cultivation and experimental design

The okra (cv. Kirikou) seeds were cultivated at the research centre of Delta State Polytechnic, Ozoro, Nigeria. The okra seeds were planted at a very close range (25 cm x 25 cm), so that tall and slender okra stems. Five treatments plans (experimental design), were adopted for the purpose of this study. The treatment plans were:

Treatment 1 (T1) = 0 mg/l ($Ca(NO_3)_2$ and was tagged the "control"
Treatment 2 (T2) = 100 mg/l ($Ca(NO_3)_2$
Treatment 3 (T3) = 200 mg/l ($Ca(NO_3)_2$
Treatment 4 (T4) = 300 mg/l ($Ca(NO_3)_2$
Treatment 5 (T5) = 400 mg/l ($Ca(NO_3)_2$

All the treatment were applied to the growing okra plant, through foliar application once weekly, until the plants were harvested for laboratory analysis as the age of 80 days. During the treatment application, each plant under each treatment plan was wetted completely, using the knapsack sprayer. All the treatments were carried in the early morning, when there was possibility of rainfall for the next four hours, according to the information collected from the department of civil engineering weather station.

Sample (okra fibre) preparation and collection

All the branches and leaves were removed from the harvested okra stems, and the fibre was extracted from the prepared stems, through the retting method. In this method, the stems were soaked inside muddy water for a period of 12 days. Then fibre were removed from the stems, washed with tap water to remove the pulp, and sun-dried for 8 days at ambient environmental conditions (Temperature ~ 28 ± 7^0C; Relative Humidity ~ 85±8).

Methods

Tensile test

The Universal Testing Machine (Testometric model), equipped with a microprocessor, was used to determine the tensile properties of the okra fibre. The tensile test was carried out according to ASTM C1557 (2003) standard recommendations. A 15 mm fibre span length was used for each tensile testing. After each test, these tensile properties (Tensile strength, Young modulus) were calculated automatically by the machine and displayed on the screen attached to it.

Biochemical analysis

The calcium and cellulose contents of the fibre were determined by according to procedures explained by Gaines and Mitchell (1979). All the laboratory tests were done at ambient temperature, and were repeated three times for each treatment.

Table 1: ANOVA results of the effect of treatment on Okra fibre tensile properties.

Source of variation	Independent variable	df	Mean square	F sat	Sig
Treatment	Tensile strength	4	8655.00	136.30	3.27E-14*
	Young Modulus	4	19.49	39.88	2.91E-09*

* = significant at ($p \leq 0.05$) according to DMRT.

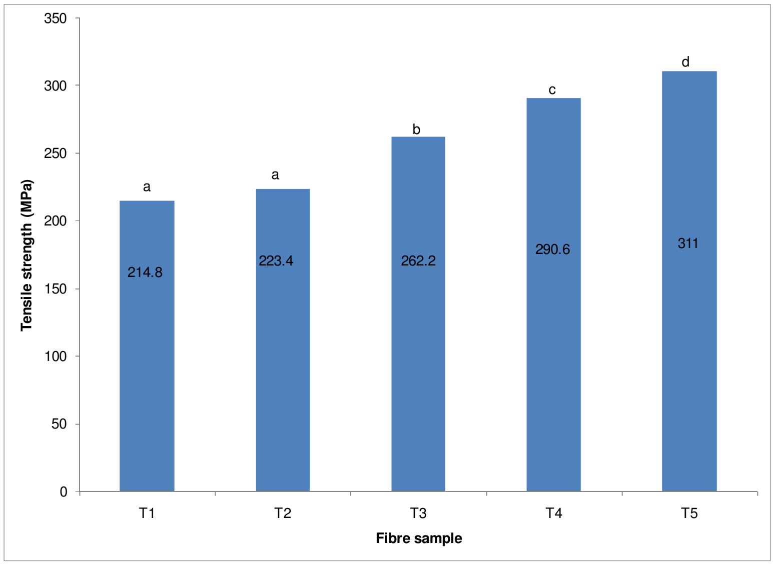

Figure 1: Tensile strength of pre-harvest treated okra (cv. Kirikou) fibre. Bars with the same common letters means that they are not significant different at ($P \leq 0.05$).

Statistical analysis

All data obtained from this study were subjected to Analysis of variance (ANOVA) using SPSS statistical software (version 20.0, SPSS Inc, Chicago, IL). Then the means will be separated using the Duncan's multiple range tests at 95% confidence level.

RESULTS AND DISCUSSION

Tensile properties

The ANOVA results presented in (Table 1), the pre-harvest treatment of okra fibre had significant ($p \leq 0.05$) effect on the tensile properties. The tensile strength of the okra fibre significantly increased from linearly, as the treatment concentration increased from 0 mg/l $Ca(NO_3)_2$ to 400 mg/l $Ca(NO_3)_2$, as given in (Figure 1). According to the study results, T1 fibre had the lowest tensile strength (214.8 MPa), while the T5 fibre recorded the highest tensile strength (311 MPa). Although, treatment option had significant effect on the tensile strength of the fibre, T1 and T2 fibre did not exhibited any differences in the tensile strength. This study portrayed the relevance of the calcium nitrate treatment on the tensile strength of the okra fibre. These results are in line with other researchers studies on pre-harvest treated of plants. Li *et al*. (2012) reported that pre-harvest calcium treatment can greatly increase the mechanical strength of plants' tissues, as it greatly increased their breaking strength of herbaceous peony (*Paeonia Lactiflora* Pall) stems. This study had further revealed that, apart post-harvest fibre modification, which is the most commonly treatment being carried out recently, plants' fibres can still be pre-harvest treated to improve their tensile properties.

Regarding the okra fibre's Young's modulus, the study showed that the Young's modulus of the fibre significantly ($p \leq 0.05$) increased as the treatment concentration increases. The control okra fibre recorded a Young's modulus value of 5.84 GPa, while the fibre treated with 400 mg/l recorded a Young's modulus of 10.76 GPa. This revealed that the stiffness of the fibre increased with an increment in the calcium nitrate concentration. As presented in (Table 2), the Young's modulus of T1 and T2, and T3 and T4 fibre looked significant similar. This is because T1 and T2 fibre did not exhibited any significant difference in their Young's modulus values; likewise, T3 and T4 fibre did not showed any significant difference in their Young's modulus results. This study further affirmed

Table 2: Okra (cv. Kirikou) fibre calcium and cellulose content.

Treatment	Cellulose (%)	Calcium (mg/100 g DW)
T1	54.00[a]±1.00	6.37[a]±0.55
T2	57.00[a]±1.73	7.30[b]±0.46
T3	65.67[b]±2.08	9.03[c]±0.32
T4	72.00[c]±1.00	10.10[d]±0.26
T5	78.33[d]±3.06	11.40[e]±0.56
Mean	65.40±9.53	8.84±1.93
Duncan ($p \leq 0.05$)	1.281E-07*	4.81E-07*

Mean± standard deviation; n=3; DW = dry weight; * = significant at ($p \leq 0.05$); columns with the same lowercase superscript letters for each parameter are not statistical different at 95% confidence level.

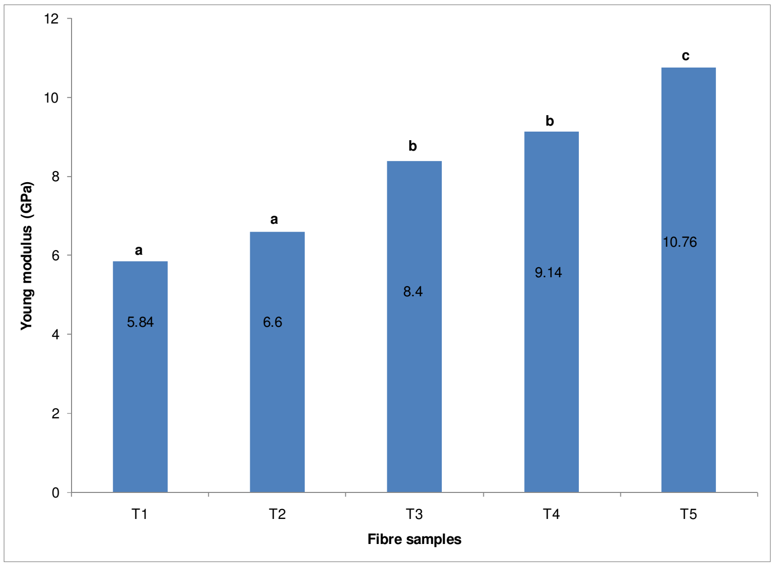

Figure 2: Young's modulus of pre-harvest treated okra (cv. Kirikou) fibre. Bars with the same common letters means that they are not significant different at ($P \leq 0.05$).

earlier assertion that calcium helped to increase the firmness of plant tissues (Figure 2). Haq and Rab, (2012) reported that calcium chloride greatly improved the mechanical properties of litchi (*Litchi chinensis* Sonn.) fruit; thereby, increasing its flexural strength and fracture resistance. Furthermore, Azeez and Onukwuli (2016) reported that tensile properties of fibre are influenced by the fiber's nature, compositions, and extraction method. The results obtain from this research will enhance high quality composite production.

Biochemical properties

Calcium content

The study showed that pre-harvest application of $Ca(NO_3)_2$ treatment of the okra fibre significantly ($P \leq 0.05$) affected the tissue calcium content (Table 2). Treatment 1 fibre had the lowest calcium content 6.37 mg/100g DW; while T5 fibre recorded the highest calcium content with the value of 11.40 mg/100g DW. As shown in (Table 2), the calcium content of the fibre increased linearly, as the treatment concentration increased from 0 mg/l to 400 mg/l. These results portrayed that foliar application of $Ca(NO_3)_2$ can improved the calcium content of plant fibre. Calcium has being experimentally confirmed of having the ability of increasing plants' tissues firmness. Peter, (2005) stated that calcium is one of the key factors that determine the tensile properties of plants fibres; thereby increasing their composite quality. This study is not only beneficial to the fibre/composite industry, but to plant breeders, as calcium is one of the essential nutrients required by plants.

Cellulose content

The results presented in (Table 2) revealed that pre-harvest calcium treatment of the okra fibre significantly ($P \leq 0.05$) affected the fibre's cellulose content. As shown in (Table 2), the cellulose content of the fibre increased significantly from T1 (54%) to T5 (78.33%), signifying the important of Calcium concentration in the formation of cellulose within the plant's tissue. However, there was no significant difference between the cellulose content if T1 fibre and T2 fibre; although the cellulose concentration increased from 54% to 57%. The results obtained from this study are with the range of the one previously reported by Alam and Khan (2007). Alam and Khan (2007) observed that the cellulose content of untreated okra fibre was 67.5 %, and the content was highl affected b sunlight duration. This study has revealed the significance of calcium nitrate pre-harvest treatment on some biochemical (calcium and cellulose) content of plant's fibre. However, more researches are need in this area to development a suitable pre-harvest treatment program for plants fibres. This study will not only improve on fibre production for the composite industry; but also increase food production, because calcium nitrate is an important fertilizer need by plants for growth and development.

Conclusion

This study was conducted to evaluate the effect of pre-harvest treatment on the tensile and biochemical properties of okra fibre. Results obtained from the study revealed that pre-harvest treatment of the okra fibre, significantly affected all the parameters tested. The tensile strength and Young's modulus of the fibre increased from 214.8 MPa to 311 Mpa, and 5.84 GPa to 10.76 GPa respectively, as the treatment concentration increased from 0 mg/l to 400 mg/l. Likewise, cellulose concentration of the fibre increased from 54. 00% to 78.33%, while the calcium content increased from 6.37 mg/100g DW to 8.84 mg/100g DW, as the $Ca(NO_3)_2$ concentration increased from 0 mg/l to 400 mg/l. These results had shown that pre-harvest treatment of okra fibre, can improve the tensile and biochemical properties of an okra fibre. This study will not only improve on fibre production for the composite industry; but also increase food production, because calcium nitrate is an important fertilizer need by plants for growth and development.

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