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Influence of Chemical Treatment on the Constituents and Tensile Properties of Selected Agro-Fibres

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Abstract: *The effect of chemical treatment on the tensile properties of Banana (Musa acuminata), Plantain (Musa parasidica), Coconut (Cocos nucifera) and Sisal (Agave sisilana) fibers was investigated. These fibres were obtained from plants in Akure, Ondo State, South-West, Nigeria and were treated with four different chemical solutions at 60 °C for 4 hours. The percentages of the fibre constituents were characterised and the tensile properties were determined using the Instron digital universal tensile testing machine. The results showed that the chemical treatment procedures had different effects on the fibers: the cellulose, hemicelluloses and lignin contents were all affected. All the chemical treatment procedures had great influence on the constituents of the fibres and their eventual tensile properties. Alkaline treatment with sodium hydroxide (NaOH) gave the best result for improved tensile strength in sisal fibre with a value of 0.81 MPa, followed by coconut fibre treated with the mixture of hydrochloric acid (HCl) and NaOH with a value of 0.69 MPa. These treatments were best for the constituents and surface modification of these selected fibres. The optimum advantage from these treatments was that, these fibers will perform better as reinforcement in composite development due to increased strength and roughed surfaces which aid binding between fibre and matrix.*

Keywords: *Chemical treatment, constituents, tensile properties, Agro fibres*

1. Introduction

Composite materials are materials that are comprised of two or more different materials and which have properties that transcend those of the individual component materials from which the composite was developed. Although the use of composite materials has somewhat waned since man discovered metals and the art of alloying, using composite materials has continued till modern times and is not likely to become obsolete anytime soon, as they continue to be useful in many engineering applications such as aerospace, civil, machine parts, automotive and household goods.

The need and use of composite materials in modern times was borne out of man's realisation that hardly does a single material possess all of the properties that are desirable. Natural fibres have been used to reinforce materials for over 3000 years. Dwindling energy resources, the emergence of new operating conditions and environmental concerns have resulted in renewed interests in bio-based materials.

Plant fibres are perceived as environmentally friendly substitutes to glass and other synthetic fibres for reinforcement in composites, particularly in automotive engineering due to their wide availability, low cost, low density, high-specific mechanical properties, and they are extracted from renewable sources-plants. They are increasingly being employed as reinforcements in polymer matrix composites (Oladele and Adewuyi, 2008). Anselm and Afiukwa (2007) investigated the mechanical properties of fibre reinforced polypropylene composite and concluded that the flexural strength, flexural modulus and Izod Impact strengths were significantly increased by a 60% fibre filling ratio. Li et al. (2009) investigated the mechanical properties of pulp fibre reinforced thermoplastic composite and the stiffness was found to increase by a factor of 5.2 and strength increased by a factor of 2.3 relative to the virgin polymer.

Natural fibres are obtained from natural sources and this includes plant/cellulosic fibres, animal/protein fibres and mineral fibres. Of the natural fibres, agro-fibres are increasingly being studied as they offer greater potential as reinforcement. Natural fibres are renewable, in so far as there is a continuous supply which will not negatively impact food security. Finding alternative, lucrative industrial uses for natural fibers will encourage unemployed youths in the developing countries to go into agriculture. Plants from which useful fibres can be obtained include banana, plantain, sisal, and coconut.

Despite the numerous potential benefits offered by natural fibres, their rapid adoption and widespread usage in the development of engineering materials has been set

back by various factors. Chief amongst these are: moisture sensitivity and absorption; thermal and dimensional instability of the developed natural fibre reinforced composite; and poor adhesion and wetting action at the fibre-matrix interface. The subsequent effects are poor load transfer between fibre and matrix; wide-spread variation in composition and properties making their characterisation difficult; entanglement of fibres, leading to uneven load distribution; and weakening of the structure (Govardan and Rao, 2011; Mohd et al., 2012; Oladele et al., 2014). All these factors lead to early failure of the developed fibre reinforced composites. The first two shortcomings are due to the hydrophilic nature of cellulose (the most abundant and load bearing constituent of the fibers). Cellulose contains numerous hydroxide (OH^-) ions which cause it to greatly absorb moisture and swell, disrupting the composite structure and resulting in poor mechanical properties and dimensional instability of the natural fibre reinforced composites (John et al., 2008; Tungjitpornkull et al., 2009).

There are two approaches to improve the interfacial adhesion between the lignocellulosic fibres and matrices. One involves the use of a separate interphase or coupling agents. The second approach to overcoming the fibre-matrix adhesion and fibre-moisture sensitivity challenge is through pretreatment of the fibres prior to their incorporation in the matrix (Dhakal et al., 2007). This is known as fibre treatment and it is done to modify the fibre surface and topology. It can be achieved by a number of process routes all of which can be categorised into physical, chemical and mechanical techniques (Mohd et al., 2012; Oladele et al., 2010).

Chemical treatment has been the most promoted fibre pretreatment technique (Fidelis et al., 2013). This is probably because of its lower energy and manpower requirements. Natural fibres have been found to have good potential for chemical treatment due to the numerous hydroxyl groups present in lignin and cellulose. Chemical treatment directly influences the fibre structures and changes their compositions, resulting in reduced moisture absorption tendencies and facilitating better bonding with the matrix materials. Chemical treatment of natural fibres prior to incorporation is done in many ways depending on the intended end properties, purpose of treatment and available reagents amongst others.

Typical chemical treatment procedures include; alkali treatment / mercerization (Chang et al., 2009), Acidic treatment/ Hydrolysis (Oladele et al., 2010) silane treatment (Bouza et al., 2008; Xue et al., 2007), acetylation (Larson-Brelid et al., 2008), benzoylation (Mohanty et al., 2001), acrylation (Huda et al., 2008), isocyanate treatment, peroxide treatment (Oladele et al., 2014, Brigida et al., 2010), permanganate treatment (Dhanalakshmi et al., 2012) and others.

The present research investigated the effect of such chemical treatments on the tensile properties of agro or (plant) fibres using readily available reagents and hybridized or combinatorial treatments. The properties and compositions of the chemically treated fibres were also compared with those from the untreated ones.

2. Materials and Methods

2.1 Materials

The major materials for this research included: Litmus papers (blue and red), solutions of potassium hydroxide (KOH), sodium hydroxide (NaOH), hydrochloric acid (HCl), sulphuric acid (H_2SO_4) distilled water and; fibres from banana (*Musa Parasidica*), plantain (*Musa Acuminata*), coconut (*Cocos nucifera*) and sisal fibres (*Agave Sisalana*).

2.2 Preparation of Fibres

Banana and plantain fibres were obtained from dew retted banana and plantain pseudo stems which were left on the farmland for 3 months after the fruits were harvested. While sisal fibre was extracted by soil retting (Oladele et al., 2014). Coconut fibres were obtained by mechanical decortications after the seeds were removed from the coconut husks. All these agro-fibers were obtained from farmland in Akure, Ondo State, South-West, Nigeria.

2.3 Chemical Treatments

The selected fibers were divided into five portions of 30 g each and subjected to the treatments outlined below. Four treatments were carried out on the fibers while the fifth part was left as the control sample.

2.3.1 Mercerisation with NaOH

A portion of each fibre type was immersed in beakers containing 500 ml of 1M NaOH solution. This was then placed in the shaker water bath maintained at 50 °C for 4 hours. The treated fibres were then removed from the beakers and washed with tap water followed by distilled water until test from litmus paper indicated pH of 7.0 which signify neutral status. The treated samples were made to dry at room temperature in the laboratory for 7 days before carrying out tests on them.

2.3.2 Mercerisation with KOH

Mercerisation was done by immersing another portion of the fibres from each plant in beakers containing 500 ml of 1M KOH solution and the same procedure as stated above under mercerisation treatment with NaOH treatment was followed.

2.3.3 Treatment with HCl + NaOH

Regarding treatment with HCl + NaOH, 500 ml solutions comprising of 375 ml of 0.75M HCl and 125 ml of 0.25M NaOH solution were prepared. The same procedure as stated above under mercerisation treatment with NaOH treatment was followed.

2.3.4 Treatment with HCl + KOH

The fourth portion of each the fibres was immersed in a beaker containing 500 ml of a reagent prepared by mixing 375 ml of 0.75M HCl and 125 ml of 0.25M KOH solution. The same procedure as stated above under mercerisation treatment with NaOH treatment was followed.

2.4 Determination of Fibre Fractions/ Proximate Analysis

The cellulose, hemicellulose and lignin contents of the fibres were determined using Goering and Van Soest's method of investigating the Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) (Goering and Van Soest, 1991; Oladele *et al*., 2010). The masses of the Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL) were obtained and used to determine the hemicelluloses and cellulose contents. Lignin content was determined using the gravimetric method.

2.5 Determination of Neutral Detergent Fibre (NDF)

The fibre samples were dried and ground into about 1mm diameter using (porcelain) laboratory mortar. 1 g of air dried ground sample was taken and placed into a beaker of refluxing apparatus. 100 ml of neutral detergent solution and about 0.5 g of Sodium Sulphite solution was then added. It was then heated to boiling and refluxed for 60 mins after the onset of boiling. The samples were then filtered into a pre-weighed crucible and washed thrice with boiling water and then twice with acetone, dried for 8 hours at 105 °C and cooled in a desiccator. The crucible was then finally reweighed and the Neutral detergent fibre was computed using:

$$\%NDF = \frac{W_2 - W_1}{W_3} X\ 100 \quad (1)$$

Where;

W_1 = weight of empty crucible,
W_2 = weight of crucible + weight of residue,
W_3 = weight of dry sample.

2.6 Determination of Acid Detergent Fibre (ADF)

The procedure is similar to that followed in determining NDF. That is, the residue after NDF determination was taken and placed into a beaker of the refluxing apparatus. 100ml of acid detergent solution (detergent+dil.H_2SO_4) was then added. The mixture was also heated to boiling and refluxed for 60mins after the onset of boiling, filtered into pre-weighed crucibles and washed thrice with boiling water and then twice with cold acetone. It was next dried for 8 hours at 105 °C, left to cool in a dessicator and finally reweighed. The ADF was then determined using the relation;

$$\%ADF = \frac{W_2 - W_1}{W_s} X\ 100 \quad (2)$$

Where;

W_1 = weight of empty crucible,
W_2 =weight of crucible + residue,
W_s = weight of sample

2.7 Determination of Lignin Content (Gravimetric method)

The procedure followed was similar to that used by Oladele et al. (2010). 1.5 g of the sample was weighed and 72 % H_2SO_4 was added and soaked for 2 hours. 8 % H_2SO_4 solution was later added and the solution was refluxed for four (4) hours. The residue was filtered with purpling cloth and washed several times with hot water. A crucible was weighed and the sample was scraped into it. The hydrolyzed sample was then oven dried at 105 ºC for two (2) hours and cooled inside desiccators after which the weight was taken. The dried sample was next ashed in the muffle furnace at 550 ºC for three (3) hours after which it was cooled inside the desiccators and finally reweighed. The % Lignin computed using the relation:

$$\%Lignin = \frac{W_2 - W_1}{W_s} X\ 100 \quad (3)$$

Where;

W_1 = weight of the ash sample + crucible,
W_2 = weight of the oven dried sample +crucible
Ws = weight of dried extractive free sample i.e. NDF residue.

The percentage Lignin content is also known as the Acid Detergent Lignin (ADL).

2.8 Determination of Cellulose content

The cellulose content of each fibre was determined using the relation:

$$\%Cellulose = ADF\text{-}ADL \quad (4)$$

2.9 Determination of Hemicelluloses Content

Hemicelluloses content was determined by using the equation:

$$\%Hemicelluloses = NDF\text{-}ADF \quad (5)$$

2.10 Tensile Testing

Tensile tests were performed on the plant fibres according to ASTM D-638**.** An Instron Universal tensile testing machine model 3369 made from Instron Incorporated USA was used. The machine applied 50 KN at a crosshead speed of 20 mm/min. Two specimens were tested from each sample after which the average was taken as the representative values.

3. Results and Discussion

3.1 Effects of Chemical Treatment on Composition of Treated and Untreated Fibres

The results of the proximate analysis of the treated fibres are presented in Tables 1, 2 and 3. As shown in Table 1 and Figure 1, alkali treatment with both KOH and NaOH

significantly improved the cellulose content of the resulting banana fibres from about 25.51 to 34.24 and 46.46 %, respectively. Treatment with NaOH performed best in this respect. This effect has been reported by Oladele et al., (2010) and can be attributed to the removal of the pectins, waxes and lignin from the fibre surface as reported by Xue et al. (2007), Jayabal, et al. (2012) and Sgriccia (2008). The hydrolysis effect of acids like HCl and H_2SO_4 on cellulose has been widely reported. Both the blend of HCl + KOH and HCl + NaOH solutions actually contain the respective chloride salts of the alkalis; KCl and NaCl in an excess of the respective acids. These excess acids are responsible for the significant reduction in cellulose content of the banana fibres.

Table 1: Proximate analysis results for the treated and untreated banana fibres

Constituent (%)	Untreated	KOH Treated	NaOH treated	HCl+KOH treated	HCl+NaOH Treated
Cellulose	25.51	34.24	46.46	9.12	24.56
Hemicellulose	2.13	5.82	7.43	2.60	11.9
Lignin	42.50	2.72	5.82	59.38	44.12

Table 2: Proximate analysis results for the treated and untreated plantain fibres

Constituent (%)	Untreated	KOH Treated	NaOH treated	HCl+KOH treated	HCl+NaOH Treated
Cellulose	24.82	2.61	36.87	3.69	10.82
Hemicellulose	12.88	1.21	22.19	2.01	3.94
Lignin	15.56	55.52	17.68	46.42	36.60

Table 3: Proximate analysis results for the treated and untreated coconut fibres

Constituent (%)	Untreated	KOH Treated	NaOH treated	HCl+KOH treated	HCl+NaOH Treated
Cellulose	15.8	22.58	4.37	35.77	10.86
Hemicellulose	0.44	5.5	38.93	9.53	6.46
Lignin	56.94	33.84	51.04	40.88	74.96

Table 4: Proximate analysis results for the treated and untreated sisal fibres

Constituent (%)	Untreated	KOH Treated	NaOH treated	HCl+KOH treated	HCl+NaOH Treated
Cellulose	4.68	30.16	1.83	0.57	1.74
Hemicellulose	43.88	48.97	45.97	62.91	50.34
Lignin	30.92	1.05	31.16	19.82	29.72

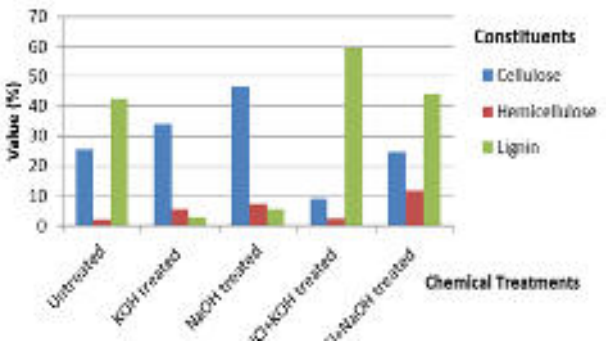

Figure 1: The proximate constituents of treated and untreated Banana fibres

3.*1.1 Effect of chemical treatments on the constituents of banana fibres*

The delignification effect of the alkalis (NaOH and KOH) may be responsible for the apparent increase in hemicelluloses content from 2.13 % for the untreated fibres to 5.82 % and 7.43 % for the KOH and NaOH treated banana fibres respectively. Rather than the reduction reported by (Lacerda et al., (2012) and ; Safinas et al. (2013), the use of HCl + KOH and HCl + NaOH treatments seemed to increase the hemicelluloses content of the banana fibres to 2.6 % and 11.9 % respectively. Although, this may be due to factors like acid concentration or possible inhibition by the dissolved salt ions. It may also be attributed to the concurrent hydrolysis of the cellulose by the excess acid, which also

takes place during the process as confirmed by the reduction in cellulose content.

Recent studies by Oladele et al. (2014) which indicate that alkali treatment reduces the lignin content of natural fibres holds good for banana fibres as shown by the reduction in lignin content from 56.94% to 51.04% and 33.84% for the 1 M NaOH and 1 M KOH treated fibres respectively (see Figure 1). As reported by Oladele et al. (2010), KOH performed better in this respect. The expected delignification effects of KOH and NaOH are non-evident in the HCl + KOH and HCl + NaOH treatments. This is because on mixing both solutions, the alkalis are completely neutralised into the normal salts (KCl and NaCl) which are dissolved in an excess of the acid.

Natural fibres are composites in which the lignin serves as matrix while the cellulose serves as reinforcement. Chemical treatments are usually carried out to modify the surface conditions of the fibers so as to be able to ensure proper adhesion between fibre and matrix. This is achieved by the removal of the deleterious constituents like lignin and hemicelluloses while retaining cellulose. The cellulose was the main constituent that enhances the strength of the fibre for engineering application (Oladele et al, 2010). Besides, the treatments will prevent the fibers from being susceptible to fungi attack.

3.1.2 Effects of chemical treatments on constituents of plantain fibres

As can be deduced from Table 2 and Figure 2, plantain fibres reacted quite differently from banana fibres when subjected to similar chemical treatments. Only NaOH treatment significantly increased the cellulose content from 24.82 % to 36.87 % (a lesser extent than was obtained in the case of banana fibres) whereas KOH treatment led to a reduction.

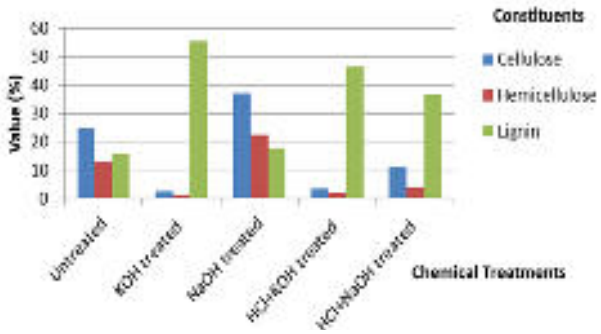

Figure 2: Tthe constituents of the treated and untreated plantain fibres

A similar situation to the cellulose response played out in the response of the hemicelluloses in plantain fibres to similar chemical treatments as those from banana. Treatment with KOH also reduced the hemicelluloses content significant to 1.21 %. In addition, the hemicelluloses in plantain fibres showed similar response but less stability to attack by the acidified salt solutions (HCl + KCl and HCl + NaCl from HCl + KOH and HCl + NaOH treatments respectively) or alkali-acid mixtures. Hemicelluloses content was reduced from 12.88 % for the untreated plantain fibres down to 2.01 % and 3.94 % for the HCl + KOH and HCl + NaOH treated fibres, respectively.

All the treatments led to an increase in lignin content. Only NaOH treatment gave marginal increase which causes it to appear to be the best treatment.

3.1.3 Effects of chemical treatments on constituents of coconut fibres

Considering the alkaline treatments, Table 3 and Figure 3, KOH treatment led to the expected increase in cellulose content from 15.8% to 22.58%, whereas NaOH treatment caused it to reduce. However, treatment with HCl + KOH causes an increase that is up to 35.77 % and was observed to be the best treatment for the enhancement of the cellulose content of the fibres.

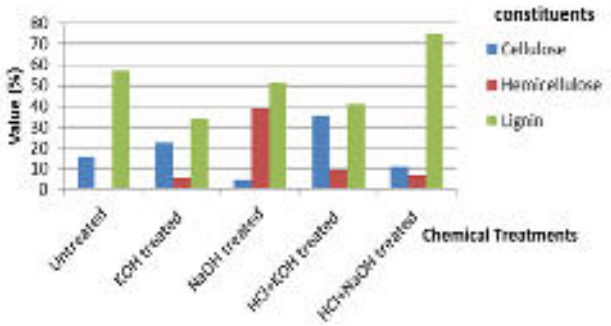

Figure 3: The constituents of treated and untreated coconut fibres

Just as with plantain fibres, coconut fibres showed different responses to alkali or mercerization treatment. All the treatments increased the hemicelluloses content of the coconut fibres, with NaOH treatment having a significantly greater effect as shown in Figure 3. This can result from the reduction in cellulose content as well as the delignification influence of the alkalis. All the treatments except HCl + NaOH led to the delignification effect. The best reduction was achieved from alkali treatment as evident in Figure 3 in which the lignin content reduced from 56.94 % to 33.84 % for the KOH treatment.

3.1.4 Effects of chemical treatments on constituents of sisal fibres

Table 4 and Figure 4 give the results of the analysis for the sisal fibre constituents. For cellulose, only KOH treatment gave improvement compared to the untreated fibre from 4.68 to 30.16 % respectively. Based on the reasons stated above, the hemicellulose content was

increased by the chemical treatments. The lignin was drastically reduced by KOH and HCl+KOH treatments from 30.92 to 1.05 and 19.82 % respectively. This shows that KOH treatment is responsible for the reduction since the best results are coming from the treatment with this chemical compared to NaOH.

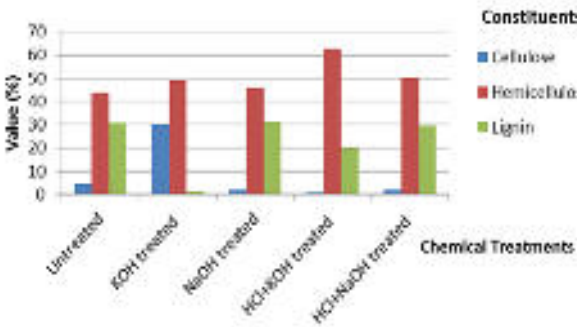

Figure 4: The constituent of treated and untreated sisal fibres

3.2 Effect of Chemical Treatment on the Tensile Properties of Agro-fibers

3.2.1 Effects on tensile strengths of banana fibres

As shown in Table 5 and Figure 5, all the chemical treatments improved the tensile properties strengths of the banana fibers. This is because these treatments in one way or the other, contributed to the removal of the unwanted constituents such as pectin, waxes, lignin and hemicelluloses. Delignification frees up the cellulose fibres to be able to stretch with less inhibition and hydrolysis of the hemicellulose further aids this effect. The hydrolyzing effect of HCl treatment on amorphous cellulose can also be responsible for the increased strengths in the HCl + KOH and HCl + NaOH treated banana fibers, as this crystalline cellulose, are able to align and stretch along the stressing axis. KOH treatment gave the best performance in this respect. The sample treated with 1 M KOH provided the best result with a value of 0.27 MPa compared to the untreated fibre with a value of 0.04 MPa.

Table 5: Ultimate tensile stresses withstood by the treated and untreated fibres

Fiber	Ultimate tensile stress after treatments (MPa)				
	Untreated	KOH treated	NaOH treated	HCl+KOH treated	HCl+NaOH treated
Banana	0.03672	0.27102	0.20071	0.19096	0.09039
Plantain	0.10896	0.17769	0.107955	0.06245	0.03719
Coconut	0.49927	0.5472	0.535	0.60184	0.68646
Sisal	0.65467	0.5843	0.81268	0.34807	0.38353

Table 6: Strain at maximum tensile stress for the treated and untreated fibres

Fiber	Tensile strain at maximum tensile stress (%)				
	Untreated	KOH treated	NaOH treated	HCl+KOH treated	HCl+NaOH treated
Banana	0.8333	9.25	4.5	4.583	3.332
Plantain	1.583	2.667	2.417	1.333	2.417
Coconut	58.084	36.75	53.667	56.417	52.417
Sisal	5.083	8.833	9.333	3.917	5.500

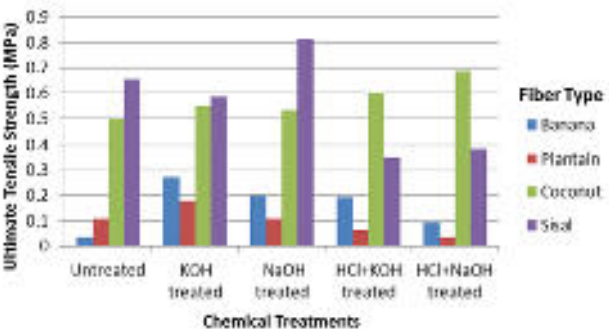

Figure 5: Variation of Ultimate Tensile Strength of the selected agro fibres in both Treated and Untreated Conditions

The other interesting thing about the performance of these chemical treatments was that the fibre surfaces will be roughened thereby making the surface readily available for proper bonding between the fibre and the matrix when use as reinforcement material for composite development.

3.2.2 Effects on tensile strength of Plantain fibres

Considering the effects of the treatment on the tensile strength of plantain fibers, only KOH treatment marginally enhanced the tensile strength of the plantain fibres from 0.11 for the untreated to 0.18 MPa for KOH treated fibre. This may be because the lignin content was increased while the cellulose content greatly reduced by this treatment. Increase in lignin content might infer better stress transfer due to proper binding effect of the residual lignin matrix that prevents excessive defibrillation of the cellulose fibrils. This aided their stretching and load distribution and thereby contributed to tensile strength improvement.

However, the removed cellulose fraction might be the crystalline form which would definitely reduce the tensile strength since the untreated fibres contain more of these. The presence of lignin makes it an unsuitable reinforcement material due to the smoothness of the surface. A smooth surface will not allow proper bonding between fibre and matrix. One of the reasons chemical treatment is being carried out was to achieve a rough surface for the fibre which will aid proper bonding between the fibre and the matrix in composite development

3.2.3 Effect on tensile strength of Coconut fibres

The results showed that all the chemical treatments improved the tensile strengths of the coconut fibres as shown in Figure 5. Treatment with the blend of 1 M HCl + NaOH gave the best performance with a value of 0.69 MPa compared to the untreated fibre with a value of 0.50 MPa. This might be due to the increased hydrolysis of amorphous cellulose fibrils (Onyeagoro, 2012) and the presence of more crystalline cellulose which has better tensile strengths than amorphous cellulose.

3.2.4 Effect on tensile strength of Sisal fibres

The results of the tensile strength property for sisal fibre shows that only mercerization with 1 M NaOH solution significantly improved the tensile strength of the sisal fibres from 0.66 to 0.81 MPa for the untreated and NaOH treated sisal fibres respectively. All the other treatment procedures investigated reduced the tensile strength of the sisal fibres. This can be attributed to the effective cleaning and delignification property of NaOH solution on the sisal fibres.

Except for the coconut fibre which showed the best enhancement in tensile strengths with synergistic treatments, the response of other fibres to the chemical treatment showed that alkali treatments with KOH and NaOH respectively were acceptable. However, by correlating the tensile strengths performance with the chemical treatments, it was noticed that the chemical treatments have influenced the fibers in different ways. These might be in connection with the interaction between the fibre constituents and the chemicals. Banana and plantain that are of the same family were observed to be highly enhanced by KOH treatment while sisal fibre was highly enhanced by NaOH treatment.

3.3 Effect of Chemical Treatment on Strain at Maximum Tensile Stress of Agro-fibers

3.3.1 Effects on the strain at ultimate tensile strength of banana fibres

The strains experienced up till maximum tensile stresses were reached for each fibre. As can be deduced from Table 6 and Figure 6, all the chemical treatment procedures had similar effect on tensile strains of the banana fibres and in this case, KOH treated fibres also experienced the highest strains of 9.25 % which can be deduced as the main reason why this sample possess the best tensile strength property. The reasons for this is as explained concerning the effects of chemical treatment on the tensile strengths of banana fibers.

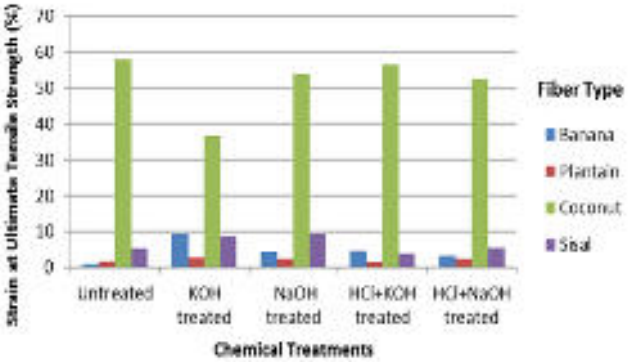

Figure 6: The strains experienced by the treated and untreated fibres at the ultimate tensile strengths

3.*3.2 Effects on strains at ultimate tensile stress of plantain fibres*

Figure 6 showed that plantain fibres had lower tensile strains than banana fibres. Almost all the treatments also showed improved tensile strains from 1.58 to 2.67 % for the untreated and KOH treated fibres respectively. This result is also in agreement with results from tensile stress and strain above for banana and plantain.

3.*3.3 Effect on strains at ultimate tensile stress of coconut fibres*

All the treatment procedures reduced the strains experienced by the coconut fibres before their tensile strengths were reached during testing. This can of course be attributed to the various effects these treatments had on the constituents of the coconut fibres. Potassium hydroxide treatment increased the cellulose and hemicellulose contents but reduced the lignin content, thus causing significant defibrillation of the fibres.

3.3.4 Effects on the strain at ultimate tensile strengths of Sisal fibres

The results in Figure 6 show that the treatments increased the strains and extension ability of the sisal fibres. The highest strain enhancement of more than 9 % was obtained with treatment using 1M NaOH solution. This was also in agreement with the result from tensile strength, where the same chemical treatment aids the best performance.

Natural fibers with good tensile properties are potential material for reinforcement in composites development with short or long strand. A very good knowledge about these will aid in the selection of the appropriate materials and production process.

5. Conclusion

This work has been successfully carried out to investigate the best treatment for the selected agro-fibers as potential reinforcement materials for the development of environmental friendly materials. From the research, it was established that:

1) All the chemical treatment procedures had great influence on the constituents of the fibres and the ensuing tensile properties. Alkaline treatments were best for the constituents and surface modification of these selected fibers: treatment of banana and plantain with 1 molar solution of KOH gave the best output while treatment with 1 molar solution of NaOH gave the best result for sisal fibre. Coconut fibre shows the most positive response to synergistic treatment in which the blend of HCl and NaOH as well as HCl and KOH gave the best results. Sisal fibre possesses the overall best tensile strength followed by coconut fibre. All except coconut fibre had their tensile strain at maximum tensile strength increased by some of the chemical treatments.
2) One objective was to compare the tensile strength properties of banana and plantain, being plants from the same family. It was discovered that banana fibre possesses higher strength than plantain fibre. It was found that at both treated and untreated conditions, banana maintains higher strength than plantain despite the fact that the plants look alike. This shows that their constituents differ.
3) The work has further substantiated the fact that chemical treatments can enhance the tensile properties of agro fibres targeted for use as reinforcement in polymer composites development for automobile applications. It was observed that all the selected agro fibres had their tensile strength enhanced relative to their individual untreated counterparts in the following order: sisal, coconut, banana and plantain.

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