INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING
WWW.IJRAME.COM
ISSN (ONLINE): 2321-3051

Vol.5 Issue.11, November 2017
Pg: -1-15

# EXPLORATION OF MECHANICAL, PHYSICAL & CHEMICAL PROPERTIES OF TERMINALIA CATAPPA FRUIT FIBER.

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## ABSTRACT

**The natural fibers nowadays play a major role as reinforcement in composites due to their important properties like lightweight, biodegradability and non-toxicity. Terminalia Catappa fruit fiber is one such type possessing high cellulose which is inexpensive and available in plenty. The Terminalia Catappa fruit fibers were extracted and its physical and chemical properties such as density, cellulose, wax, moisture were experimentally determined. In this study, the Terminalia Catappa fruit fibers were treated with 5% and 10% of NaOH and the effect of alkali treatments on the fiber properties were explored.**

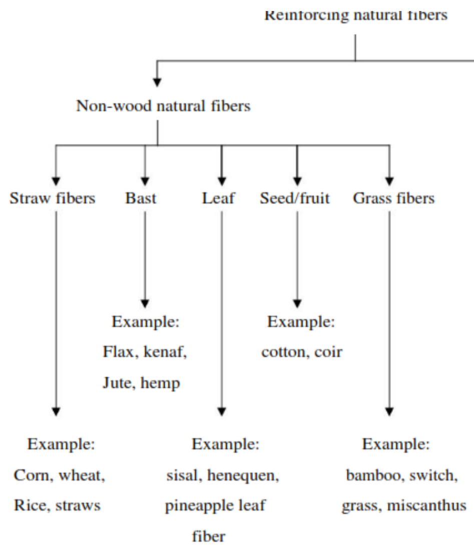
## I. INTRODUCTION

Over the past two decades, polymer-based materials reinforced with various natural fibers have been established everywhere from academic and industrial point of view. Environmental consciousness, legislation, and energy consumption have inspired academics and industrial researchers working in the area of cellulose fibers and fiber-reinforced composite. More than 1000 species of cellulose plants are being available in fibers forms and few of them are investigated to prepare the reinforced composite. The natural fiber composites have attractive features likes low cost, light-in weight, moderated strength, high specific modulus, moderate mechanical properties, easy to handle, and lack of health hazards compared to synthetics fiber composite. Structure of the fiber is framed with natural chemicals such as cellulose, lignin, and wax. The cellulose fiber-reinforced composites have been significantly used for industrial components, construction material, automobile parts, and home appliances.

The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lignocelluloses fibers, are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites. The natural fiber-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products, etc.

# II. CLASSIFICATION OF NATURAL FIBER

Fibers are a class of hair-like material that are continuous filaments or are in discrete elongated pieces, similar to pieces of thread. They can be spun into filaments, thread, or rope. They can be used as a component of composites materials. They can also be matted into sheets to make products such as paper or felt. Fibers are of two types: natural fiber and manmade or synthetic fiber.




Natural fibers include those made from plant, animal and mineral sources.
Natural fibers can be classified according to their origin.

- Animal fiber
- Mineral fiber
- Plant fiber

**Animal Fiber**

Animal fiber generally comprise proteins; examples mohair, wool, silk, alpaca, angora.

**Animal hair (wool or hair)**

Fiber taken from animals or hairy mammals. e.g. Sheep's wool, goat hair (cashmere, mohair), alpaca hair, horse hair, etc.

**Silk fiber**

Fiber collected from dried saliva of bugs or insects during the preparation of cocoons.

Examples include silk from silk worms.

**Avian fiber**

Fibers from birds, e.g. feathers and feather fiber.

**Mineral fiber**

Mineral fibers are naturally occurring fiber or slightly modified fiber procured from minerals. These can be categorized into the following categories:

**Asbestos**

The only naturally occurring mineral fiber. Varietions are serpentine and amphiboles, anthophyllite.

**Ceramic fibers**

Glass fibers (Glass wood and Quartz), aluminum oxide, silicon carbide, and boron carbide.

**Metal fibers**

Aluminum fibers.

**Plant fiber**

Plant fibers are generally comprised mainly of cellulose: examples include cotton, jute, flax, ramie, sisal and hemp. Cellulose fibers servers in the manufacture of paper and cloth. This fiber can be further categorizes into following.

**Seed fiber**

Fibers collected from the seed and seed case e.g. cotton and kapok.

**Leaf fiber**

Fibers collected from the leaves e.g. sisal and agave.

**Skin fiber**

Fibers are collected from the skin or bast surrounding the stem of their respective plant. These fibers have higher tensile strength than other fibers. Therefore, these fibers are used for durable yarn, fabric, packaging, and paper. Some examples are flax, jute, banana, hemp, and soybean.

**Fruit fiber**

Fibers are collected from the fruit of the plant, e.g. coconut (coir) fiber.

**Stalk fiber**

Fibers are actually the stalks of the plant. e.g. straws of wheat, rice, barley, and other crops including bamboo and grass. Tree wood is also such a fiber. The natural fibers can be used to reinforce both thermosetting and thermoplastic matrices.

IJRAME

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WWW.IJRAME.COM
ISSN (ONLINE): 2321-3051

Vol.5 Issue.11,
November 2017
Pg: -1-15

Thermosetting resins, such as epoxy, polyester, polyurethane, phenolic, etc. are commonly used today in natural fiber composites, in which composites requiring higher performance applications.

They provide sufficient mechanical properties, in particular stiffness and strength, at acceptably low price levels. Considering the ecological aspects of material selection, replacing synthetic fibers by natural ones is only a first step. Restricting the emission of green house effect causing gases such as CO2 into the atmosphere and an increasing awareness of the finiteness of fossil energy resources are leading to developing new materials that are entirely based on renewable resources.

# III. LITERATURE SURVEY

As a result of the increasing demand for environmentally friendly materials and the desire to reduce the cost of traditional fibers (i.e., carbon, glass and aramid) reinforced petroleum-based composites, new bio-based composites have been developed. Researchers have begun to focus attention on natural fiber composites (i.e., biocomposites), which are composed of natural or synthetic resins, reinforced with natural fibers. Natural .bers exhibit many advantageous properties, they are a low-density material yielding relatively lightweight composites with high specific properties. These fibers also o.er significant cost advantages and ease of processing along with being a highly renewable resource, in turn reducing the dependency on foreign and domestic petroleum oil. Recent advances in the use of natural fibers (e.g., .ax, cellulose, jute, hemp, straw, switch grass, kenaf, coir and bamboo) in composites have been reviewed by several authors [6–25].

Harish et al. [1] developed coir composite and mechanical properties were evaluated. Scanning electron micrographs obtained from fracture surfaces were used for a qualitative evaluation of the interfacial properties of coir /epoxy and compared with glass fibers.

Wang and Huang [2] had taken a coir fiber stack, characters of the fibers were analyzed. Length of the fibers was in the range between 8 and 337 mm. The fibers amount with the length range of 15~145mm was 81.95% of all measured fibers. Weight of fibers with the length range of 35~225 mm accounted for 88.34% of all measurement. The average fineness of the coir fibers was 27.94 tex. Longer fibers usually had higher diameters. Composite boards were fabricated by using a heat press machine with the coir fiber as the reinforcement and the rubber as matrix. Tensile strength of the composites was investigated.

Nilza et al. [3] use three Jamaican natural cellulosic fibers for the design and manufacture of composite material. They took bagasse from sugar cane, banana trunk from banana plant and coconut coir from the coconut husk. Samples were subjected to standardized tests such as ash and carbon content, water absorption, moisture content, tensile strength, elemental analysis and chemical analysis.

Bilba et al. [4] examined Four fibers from banana-trees (leaf, trunk) and coconut-tree (husk, fabric) before their incorporation in cementitious matrices, in order to prepare insulating material for construction. Thermal degradation of these fibers was studied between 200 and 700 °C under nitrogen gas flow. Temperature of pyrolysis was the experimental parameter investigated. The solid residues obtained were analyzed by classical elemental analysis, Fourier Transform Infra Red (FTIR) spectroscopy and were observed by Scanning Electron Microscopy (SEM).This study has shown (1) the relation between botanical, chemical composition with both localization of fiber in the tree and type of tree; (2) the rapid and preferential decomposition of banana fibers with increasing temperature of pyrolysis and (3) the rough samples are made of hollow fiber.

Conrad [5] investigates the connection between the distribution of lignin and pectin and the loading of Pb and Zn on coir. The coir consisted mainly of xylem and a fiber sheath. The lignin was evenly distributed in the cell walls of the fiber sheath, but in the xylem, there was no detectable content in the compound middle lamella, and a smaller content of lignin in the secondary walls than in the walls of the fiber sheath. The only detectable content of pectin in the fiber sheath walls was in the middle lamella, cell corners and extracellular matrix, while in the xylem, the pectin was almost evenly distributed in the wall, with a higher concentration in the middle lamella and cell corners. All cell walls facing the lacuna had a high content of pectin. Simple correlation between the loading of metal ions and the distribution of lignin or pectin, these investigations point at no correlation with lignin and a positive correlation with pectin.

Passipoularidis and Philippidis [6] studied the influence of damage accumulation metric, constant life diagram formulation and cycle counting method on life prediction schemes for composite materials under variable amplitude (VA) loading. Results indicate that a net improvement is achieved when linear strength degradation is implemented as damage metric in life prediction schemes, over the state-of-the-art PM summation.

Din et al. [7] investigated the liquid-phase adsorption of phenol onto coconut shell-based activated carbon for its equilibrium studies and kinetic modeling. Coconut shell was converted into high quality activated carbon through physiochemical activation at 850 ◦C under the influence of CO2 flow. Beforehand, the coconut shell was carbonized at 700 ◦C and the resulted char was impregnated with KOH at 1:1 weight ratio. A series of batch adsorption experiments were conducted with initial phenol concentrations ranging from 100 to 500mgl−1, adsorbent loading of 0.2 g and the adsorption process was maintained at 30±1 ◦C. Chemical reaction was found to be a rate-controlling parameter to this phenol-CS850A batch adsorption system due to strong agreement with the pseudo-second-order kinetic model. Adsorption capacity for CS850A was found to be 205.8mgg−1.

Rao et al. [8] aims at introducing new natural fibers used as fillers in a polymeric matrix enabling production of economical and lightweight composites for load carrying structures. An investigation of the extraction procedures of vakka, date and bamboo fibers has been undertaken. The cross-sectional shape, the density and tensile properties of these fibers, along with established fibers like sisal, banana, coconut and palm, are determined experimentally under similar conditions and compared. The fibers introduced in the present study could be used as an effective reinforcement for making composites, which have an added advantage of being lightweight.

Dick et al. [9] conduct static and cyclic 4-point bending tests on glass-filled polycarbonate, to collect results for evaluation of a theoretical model on its capability to predict the fatigue life and the residual strength after the cyclic loading The study quantifies the effects of loading conditions, i.e. the stress ratio and the maximum stress level, on the damage development. The paper demonstrates the possibility of expressing each of the model parameters as a function of single variable that is stress ratio, maximum stress level, or a material-dependent constant.

Ersoy and Kucuk [10] investigated the sound absorption of an industrial waste, developed during the processing of tea leaves. Three different layers of tea-leaf-fiber waste materials with and without backing provided by a single layer of woven textile cloth were tested for their sound absorption properties. The experimental data indicate that a 1 cm thick tea-leaf-fiber waste material with backing provides sound absorption which is almost equivalent to that provided by six layers of woven textile cloth. Twenty millimeters thick layers of rigidly backed tea-leaf-fibers and non-woven fiber materials exhibit almost equivalent sound absorption in the frequency range between 500 and 3200 Hz.

**ADVANTAGES OF NATURAL FIBER COMPOSITES**

Low specific weight, resulting in a higher specific strength and stiffness than glass fiber.

It is a renewable source, the production requires little energy and $CO_2$ is used while oxygen is given back to the environment.

Production with low investment at low cost, which makes the material an interesting product for low wage countries.

Good thermal and acoustic insulating properties.

**PROBLEM IDENTIFICATION**

To fabricate an alternative material for costly products this is economically available alternative and should be easy to fabricate.

To avoid holes present in the resin are due to fiber pull-out due to the tensile load.

The presence of uneven fibers causes the poor flexural strength and impact strength.

Choosing the fiber length, fiber volume fraction and fiber orientation is very important, since the influence the following characteristics of a composite laminate like tensile strength, fatigue strength, etc…,

The abrasion behavior of AFPC was affected by the length of the chopped AF and by the relative orientation of the AF with respect to the rubbing surface.

We use the Terminalia catappa fiber and epoxy resin it is good in compressive strength and tensile strength etc…,

The sisal, roselle, flax, banana is very good in any one of mechanical properties. But we need of composite materials as good in all mechanical properties such as tensile strength, flexural strength, impact strength etc…

**METHODOLOGY**

Terminalia catappa fruit fiber reinforced composites are fabricated with varying aspects ratio of fibers and volume fraction (30 & 40% respectively).

Abrasive wear behavior of polymer reinforced with natural fiber was studied

(TERMINALIA CATAPPA FIBER).

Temperature with standing capacity of AFPC was analyzed.

The fabrication processes were done by using hand layup technique.

The mechanical properties such as tensile, flexural strength and impact test were analyzed as a function of fiber loading as per ASTM standards.

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Vol.5 Issue.11,
November 2017
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## EXTRACTION OF TERMINALIA CATAPPA FIBER

The matured Terminalia Catappa fruits were collected from Terminalia Catappa fruit trees and immersed in water for two days. The flush which was bonded with the fibers absorb water and the retting of the same started. The flush lost its bonding strength at this stage. Now the fruits were taken out of water and thoroughly washed in running water. During the washing process the fruits were gently pressed for the removal of the retted flush. The fruits were then immersed in water for one day and the process was repeated for the removal of remaining flush. The fibers were taken out and allowed to dry in the shadow for a couple of days. The fibers were then dried in sunlight for half an hour and extracted.

Fig no:5.3(A)


Fig no:5.3(B)

### Properties of epoxy resin

**Tabulation:5.4.1**

| | |
|---|---|
| Glass transition temperature (Tg) | 120-130°C |
| Tensile strength | 85 N/mm$^2$ |
| Tensile modulus | 10,500 N/mm$^2$ |
| Elongation at break | 0.8% |
| Flexural strength | 112 N/mm$^2$ |
| Flexural modulus | 10,000 N/mm$^2$ |
| Compressive strength | 190 N/mm$^2$ |
| Coefficient of linear thermal expansion | 34 10-6 |
| Water absorption -24 hours at 23°C | 5-10 mg(0.06-0.068%)ISO 62(1980) |

## APPLICATION FOR EPOXY RESINS ARE EXTENSIVE

Adhesives, bonding, construction materials (flooring, paving and aggregates), composites, laminates, coatings, molding and textile finishing. They have recently found uses in the air and spacecraft industries.

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The application for epoxy based materials are extensive and include coatings, adhesives and resin matrices for composite materials such as those using carbon fiber and fiberglass reinforcements (although polyester, vinyl ester and other thermosetting resins are also used for glass-reinforced plastic). The chemistry of epoxies and the range of commercially available variations allow cure polymers to be produced with a very broad range of properties.

In general epoxies are known for their excellent adhesion, chemical and heat resistance, good-to-excellent mechanical properties and very good electrical insulating properties.

Many properties of epoxies can be modified (for example silver-filled epoxies with good electrical conductivity are available, although epoxies are typically insulating).

Variations offering high thermal insulation or thermal conductivity combined with high electrical resistance for electronic applications are available.

**Advantages of EPOXY RESIN**

Mechanical and thermal properties

High water resistance

Long working high times available

Low cure shrinkage

**ALKALI TREATMENT OF FIBERS**

The dry Terminalia Catappa fibers were treated with 5% and 10% NaOH solution separately for about 0.5 hour at room temperature. The fibers were then washed with fresh water to take away any NaOH sticking on the fiber surface. The fibers were neutralized with 2.5% Hcl solution at room temperature. The fibers were again washed in distilled water and dried at room temperature for 24 hour. The 5% and 10% NaOH alkali treated Terminalia Catappa fruit fibers.

**MECHANICAL PROPERTY TESTING**

The following mechanical properties of the natural fiber composite material reinforced with Acacia for different volume of fraction 30-70 & 40-60 were determined during this investigation.

- Tensile strength
- Flexural strength
- Impact test

**Tensile strength**

It is the maximum stress that a material can withstand while being stretched or pulled before necking when the specimen's cross section starts to significantly contract. It is found by performing a tensile test and recording the stress versus strain, the highest point of the stress-strain curve is the ultimate tensile stress. It is an intensive property; its value does not depend on the length of the test specimen. It is depend on other factor, including preparation of the specimen, the presence of surface defects and the temperature of the test environment and material.

Tensile test was carried out by applying tensile load. Tensile test was carried out by using universal testing machine. The volume fraction of fiber is 30% and 40%.

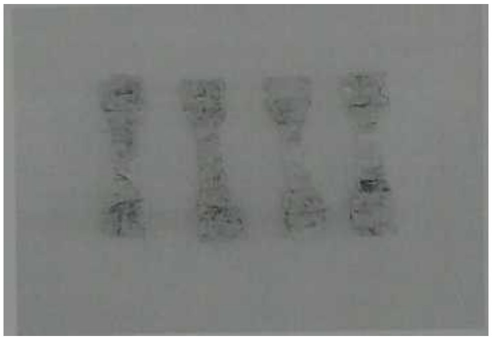

Fig no:3

**Flexural strength**

Flexural test was carried with the three point load of two side supported and load acting on the centre of the specimen. Continuously increasing the load acting on the specimen we calculated the deformation of the different volume of fraction.

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Fig no:5

**Impact strength**

The purpose of impact testing is to measure an objects ability to resist high-rate loading. It is usually thought of in terms of two objects striking each other at high relative speeds. A part or material's ability to resist impact often is one of the determining factors in the service life of a part or in the suitability of a designated material for a particular application. Impact resistance can be one of the most difficult properties to quantity. The ability to quantity this property is a great advantage in product liability and safety.

Impact Testing most commonly consist of charpy and IZOD specimen configurations. The charpy impact test are conducted on instrumented machines capable of measuring less than 1ft.lb. to 300ft.lbs. at temperature ranging from -320˚F to over 2000˚F. impact specimen types include notch configurations such as V-Notch, U-Notch, Key-Hole Notch, as well as UN-Notched and ISO (DIN) V-Notch, with capabilities of impact testing sub size specimens down to ¼ size. IZOD impact testing can be done up to 240ft.lbs. on standard sin gle notch and type-X3 specimens.

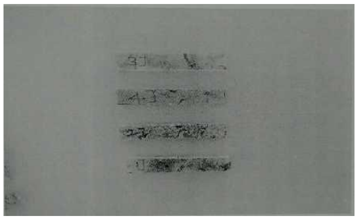

**Fig no: 6**

**PHYSICAL PROPERTIES**

**Fiber density**

The water displacement method was employed to find the density of the Terminalia Catappa fruit fiber. The weighed quantity of fiber was completely immersed in water and the volumetric displacement was observed. The weight to volume ratio yielded the density value.

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**CHEMICAL PROPERTIES**

**Wax content**

The wax content was measured with the help of sox lot apparatus. Petroleum benzene liquid was heated to 70°C and one gram of Terminalia Catappa fruit fiber was immersed in the liquid. The 1hour reflux time was provided and the fiber sample was dried. After drying the fiber, it was weighed and weight difference confirmed the wax content.

**Moisture content**

The weighed quantity of Terminalia Catappa fruit fiber was placed in an oven at the temperature range of 105 ± 2°C for 4 hour. The weight of the fib er taken from the oven was measured and the difference in weight accounts for the moisture content present in the fiber.

**Cellulose content**

The weighed quantity of Terminalia Catappa fruit fiber was immersed in a mixture of sodium chloride 1.72%, and three drops of sulfuric acid in water. One hour soaking time was provided. Then the excess fluid was taken away by suction process and ammonia was added. The residue was washed with distilled water, dried at room temperature and weighed. The percentage of cellulose was noted by the ratio of the residue weight to the dry sample weight.

# IV. RESULT AND DISCUSSION

Result have been presented using on basis of volume of fraction with the mechanical properties are tensile strength, flexural strength, impact strength and physical properties and chemical properties test were calculated.

**Tabulation:**

| VOLUME OF FRACTION | CS AREA $(mm)^2$ | PEAK LOAD (N) | FLEXURAL STRENGTH (Mpa) | FLEXURAL MODULUS (Gpa) |
|---|---|---|---|---|
| 80:20 | 77 | 147.425 | 25.847 | 1030.475 |
| 70:30 | 77 | 326.418 | 57.229 | 455.029 |

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**MECHANICAL PROPERTIES**

**Tensile test**

Result of tensile test is significant difference in tensile strength and modulus for laminates made with treated and untreated natural fiber composite. For the 20% and 30% fiber volume fraction made using treated and untreated fiber. Tabulation of different volume of fraction with load, displacement, % of elongation, tensile strength, is noted. Tensile strength of treated fiber is more when compared to untreated fiber and also the

specimen which is used for moisture absorption is also treated. Tensile strength is less in moisture absorption.

**Tabulation:**

| VOLUME OF FRACTION | CS AREA $(mm)^2$ | PEAK LOAD (N) | % ELONGATION | UTS $(N/mm^2)$ |
|---|---|---|---|---|
| 70:30 | 78 | 987.887 | 1.40 | 12.665 |
| 80:20 | 78 | 826.208 | 1.220 | 10.595 |

**Flexural test**

Result of flexural test is significant difference in flexural strength and modulus for laminates made with treated and untreated natural fiber composite. For the 20% and 30% fiber volume fraction made using treated and untreated fiber. Tabulation of different volume of fraction with load, displacement, %of elongation, flexural strength, flexural modulus is noted. Flexural strength of treated fiber is more when compared to untreated fiber and also the specimen which is used for moisture absorption is also tested.

**Impact test**

The impact test is a method for evaluating the toughness and notch sensitivity of engineering materials. It is usually used to test the toughness of metals the hybrid composite has the high amount of energy required for pulling it out. The notched test specimen is broken by the impact of a heavy pendulum or hammer, falling at a predetermined velocity through a fixed distance. The test measures the energy absorbed by the fractured specimen.

**Tabulation:**

| VOLUME OF FRACTION | IMPACT VALUE IN $J/mm^2$ |
|---|---|
| 70:30 | 0.25 |
| 80:20 | 0.35 |

## PHYSICAL PROPERTIES OF TERMINALIA CATAPPA FRUIT FIBER

The results are shown in Table 1.It was noticed that the density values of the Terminalia Catappa fruit fibers were less than that of the synthetic fibers.This property envisage that the Terminalia Catappa fruit fibers could be used as reinforcements in making the light weight composite structures. Moreover the biodegradability is an added feature for the use of this fiber in composites.

**Tabulation:**

| S.No | Type of fiber | Density value g/cc |
|---|---|---|
| 1 | Raw fiber | 1.31 |
| 2 | 5% Alkali treated fiber | 1.28 |
| 3 | 10%Alkali treated fiber | 1.26 |

## CHEMICAL PROPERTIES OF TERMINALIA CATAPPA FRUIT FIBER

The Terminalia Catappa fibers were alkali treated with 5%, 10% NaOH solution and the outcomes are presented in Table. The change in fiber properties was observed due to alkali treatment. The raw Terminalia Catappa fruit fiber consists of cellulose (66.95%), wax (0.44%) and moisture (13.5%). The alkali treatment caused the cellulosic fiber to swell and removed the cellulose and other impurities from the fiber surface. The micro fibrils of cellulose remained unaffected due to alkali treatment. The removal of the impurities led to the better mechanical properties, fiber wetting characteristics and fiber– matrix adhesiveness in composite applications.

**Tabulation:**

| Fiber category | Wax content (wt%) | Moisture content (wt.%) | Cellulose content (wt.%) |
|---|---|---|---|
| Raw fiber | 0.44 | 13.5 | 66.95 |
| 5% Alkali treated fiber | 0.24 | 14.8 | 65.49 |
| 10% Alkali treated fiber | 0.16 | 14.85 | 60.11 |

## V. CONCLUSION

- The potential use of natural fibers has been discussed in this work. The physical and chemical properties of Terminalia Catappa fiber were studied and analyzed in this work.

- The mechanical properties of raw and alkali treated fibers were going to be analyzed by INSTRAN 5500 R-60211 machine.

- The morphological study of raw and alkali treated fibers were going to be analyzed with Scanning Electron Microscope (SEM).

- The physical, chemical and mechanical properties of raw Terminalia Catappa fiber will be compared with 5% and10% of NaoH Terminalia Catappa fiber. Among these, best properties will be chosen and it will be again compared with existing natural fiber composites. Then we will propose to fabricate a new composite by replacing existing natural fiber composites.

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