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PROCESS ENGINEERING STREAM

MASTER'S THESIS

EXTRACTION, CHARACTERIZATION AND OPTIMIZATION OF BANANA
TRUNK FIBER

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***A RESEARCH SUBMITTED TO ADDIS ABABA INSTITUTE OF TECHNOLOGY FOR THE PARTIAL
FULFILMENT OF MASTERS OF SCIENCE IN PROCESS ENGINEERING.***

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ETHIOPIA

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PREPARED BY

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DECLARATION

I announce this thesis as my own work .This thesis is being submitted to the Addis Ababa Institute of Technology for the degree of Masters of science in chemical engineering (process engineering) . I declare that this work is our own and has not been submitted before for any degree or examination to this or any other university or institution for this or any other degree or award. As the same time a possible attempt to get any degree award with the same paper considered as plagiarism.

Student

Milkiyas Dandesa

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ABSTRACT

Banana plants do not only give delicious fruit but it can also provide banana fiber. Production of natural fiber is expected to increase because their production mostly centered on environmental friendly process and renewable. As a result production of natural fiber to satisfy the needs could take advantage over the synthetic fiber production in this regard.

This study aimed at production, characterization and optimization of further process ability and mechanical property performance improvement of mechanically extracted banana fiber. So the final outcome of the research is to produce high quality banana trunk fiber which can be used in different sectors. The fiber is extracted manually by mechanical process. This is because of the fiber extracted mechanically was found to be appropriate for yarn spinning and knitting, have better color and tensile properties as well as the process is time conserving. The fiber obtained was treated with 0.1M, 0.3M and 0.5M of NaOH for different treatment time duration of 30min, 45min and 60min at the temperature of 30^oc, 60^oc and 90^oc. The fiber is treated with different concentration of chemical such bleaching agent hydrogen peroxide(5%) and lubricants such as castor oil (10%), sodium silicate(10%), soap(10%) and acetic acid(10%).

Three parameters of treatment which are temperature, time and concentration was investigated. The effect of each parameter on the mechanical properties of the fiber was studied carefully by keeping the two other constant during treatment. In this study the obtained fiber is standardized (conditioned) at 20^oc and relative humidity of 60% for 24hr according to the standard method before the tensile test for textile fiber to ensure environmental equilibrium moisture content. The linear density of the banana fiber is determined for treated and non-treated using ASTM-D-6612 by putting 200mm of or both treated and untreated banana fiber in linear density measuring device. The linear density of untreated banana fiber is found to be 9.00Ne while for treated bleached and lubricated banana fiber is found as 26.80Ne.

Finally the fiber was tested for its strength and other properties using yarn testing machine TEXTECHNO STATIMAT ME+ BY using ASTM: D -3822-07(ISO2062-500). It is found that treated banana fiber at a temperature of 90^oc with 0.3M of NaOH for 60minute produced the best quality and superior property in terms of tensile properties such as elongation, maximum force, work to break tenacity and time to break.

1. INTRODUCTION

1.1.BACKGROUND

Banana is the rhizomatous plants that currently grown in more than 120 countries around the world (Japan echo inc.2005, Indian horticulture database, 2011). Different parts of banana trees serve different purposes, including fruits as food sources, leaves as food wrapping, and stems for fiber and paper pulp.

Historically, banana stems had been used as a popular source of fiber with the earliest evidence around the 13th century in Egypt (Anonymous.2007). But as fiber industry has been developing in production efficiency and new fibers were then developed to effectively to respond the consumers need, including the production of man-made fibers using petroleum products its popularity was faded. More convenient fibers such as cotton and silk were also made available. Banana is a food crop which is cultivated for its fruit and used less chemicals as compared with chemicals used for fiber producing crops which make its production preferable. Not only contamination of environment due to chemical used in other fiber producing crops but also an increase in global population and thereby increase the demand of textile fiber force mankind to search additional fibers apart from cotton and other synthetic fiber. So it is undeniable that the future situation leads us to turn our face to other alternative natural fiber source such as banana fibers in coming years.

In banana plantations, after the fruits are harvested, the trunks or stems will be wasted. Billion tons of stems and leaves are thrown away annually worldwide (Johnston T. 2003). Banana trunk has less amount of extractive, proteins ,starch and other organics which makes it preferable fiber source. The fiber contains several polymers such as cellulose, hemicellulose , pectins and lignin that constitute fibers with good mechanical properties.If such waste provides sustainable sources of fibers, it will leads to the reduction of other natural and synthetic fibers production that requires extra energy, fertilizer, extra cost, extra time and chemical. The banana fiber is a ligno-cellulosic fiber with good absorption , highly breathable and quickly dry with high tensile strength. It is a bast fiber which has relatively good mechanical properties and can be obtained at low production cost as it is obtained from agricultural waste. So it could be used effectively in different sectors. It is known that the use of Banana fiber in the textile and other sectors such as glass fiber and composite material production industry is a new concept for Ethiopia. However, certain amount of research has been done on banana fiber by some scholars worldwide. Accordingly it has been found that banana fiber can be a very promising source of natural fiber in the coming period.

It may be noted that this fiber is already used successfully in Philippines,Malaysia, Japan and Korea in textile industry and other sectors (Dr.Ventakasubramanian.et al). In

Australia paper with better quality and durability was made from banana fibers (Belinda Steining, 2003). In Costa Rica industrial production of paper from pseudo stem is going on full scale (C. Vigneswaran et al. 2015). In India there are a good number of banana fiber extraction units which have been running very successfully. Some of them are exporting the banana fiber products (Prem Dubey, 2016). Even if using banana fiber in textile and other sector is new technology, it is mentioned that some countries are already started using it. The question is can we do the same in our country Ethiopia? This research is intended to answer this question. Currently Ethiopia produces more than 100,000 tons of bananas annually. As an agro waste a huge amount of banana trunk is produced. Because of lack of technology and knowledge we are not using it even in small amount. Other countries like India, Japan and Australia are already started to use this agro waste effectively and efficiently. These countries use in production of fabrics, paper, rugs, scarves, bags, belts, baskets, sandals, shoes, curtains, hats, photo frames, gift bags etc. So in general doing extensive research in this area could benefit the country a lot.

Banana fiber can be extracted in different ways. There are ways of extracting banana fiber. Manually using iron ribbon, mechanically using machine, and chemically using chemicals, natural retting method and biologically using enzymes. All of them have their own benefits and drawbacks. Manually high quality fiber could be obtained but it is time consuming and not suitable for mass production. Mechanically low quality of fiber compared to manual extraction method but suitable for mass fiber production. Chemical extraction is time consuming and less attractive colored fiber could be obtained. Natural retting method is again time consuming and less quality fiber with unattractive color fiber could be produced. Biological method of extraction of banana fiber is novel process in producing high quality fiber without contaminating environment but it is time consuming and costly as compared to other methods. In this research manual extraction using fresh method is selected to investigate the properties of banana fiber. Because it is less time consuming and economical which can produce enough amount of fiber for investigation. Hoping that we could utilize our natural fiber resources in the near future by filling our knowledge and technology gap, this research is intended to produce, characterize and optimize banana fiber and to investigate improvement of mechanical property. It also aimed at studying the crucial production parameters (concentration, temperature and treatment time length) effects on mechanical properties and performance of banana fiber. The ultimate goal of the thesis is to produce high quality banana fiber and introduce it into Ethiopian textile industry or any other sector such as fiberglass and composite material production.

1.2.STATEMENT OF THE PROBLEM

Reliable fiber is the concern of any textile, fiberglass and composite material production industry. In Ethiopia there is no factory or firm which produce promising amount of synthetic fiber or natural fiber apart from cotton yet. But there is still a capacity to produce huge amount of natural fiber from plants such as banana and false banana (enset) ,sisal and grass bast fibers. Actually there is some amount natural fiber produced from false banana locally where as in most part of Ethiopia using it as a source of food.

False banana is produced for food and it takes longer period of time(2-4 years) to harvest or to reach maturity level and thereby obtain fiber. But banana takes only 8-12 month to reach its maturity level and harvesting fruit. That means there is a huge amount of trunk to be wasted at less than or equal to a year. According to Ethiopian horticulture institute Currently Ethiopia produces about 100,000 tons of bananas annually(2014 report). But none of the banana trunk is used as a source of fiber. In Ethiopian banana farms this huge amount of pseudo stem considered as waste and pollute environment through emission of certain greenhouse gases and other pollutant gases as result of putrefaction.The country is losing in both economic and environmental protection wise .Currently Ethiopian textile industry sector is suffering from lack of cellulosic natural fiber such as cotton. According to the current static of Ethiopian statistical agency about 40% of the current demand is covered through import from other country. The import processes have its own impact on the development of this sector due to various reasons such as delay and other market drive factors.

The population of Ethiopia is increasing so it is undeniable there will be an increase in demand of natural fiber such as cotton in Ethiopian textile industry. The country is lacking to fulfill the current demand while there will be is an increase in demand of cellulosic fiber in coming years. So it is undeniable we need to turn our face for alternative fiber source such as banana fiber. The fiber can also used in car body building as matrix, fiber glass industry and other composite material production. Despite of these advantages, up to the completion of this thesis there is no observable attempt of using banana fiber yet in our country Ethiopia.

Even if there is no one clear reason that hinders our country from using this natural fiber despite of its availability , lack of well-organized study, knowledge and technology related to usage of natural fiber(except cotton) plays a major role.

1.1 Objectives

1.3.1 General objectives

The main objective of this thesis work is to characterize and optimize banana fiber production and to evaluate the extracted banana fiber with respect to chemical and physical properties in comparison with untreated extracted fiber.

1.3.2 Specific objectives

- ❖ To produce banana trunk fiber mechanically using fresh method , characterize the obtained fiber and modify the mechanical properties of banana fiber through physicochemical methods.
- ❖ To study the effect of various chemical treatment such as sodium hydroxide(0.1M- 0.5M) hydrogen peroxide(5%) and lubricants such castor oil (10%),sodium silicate(10%) ,soap(10%) and acetic acid(10%) on banana fiber.
- ❖ To optimize the production process, mechanical property and process ability performance improvement of treated banana fiber by controlling parameter such as temperature, concentration and treatment time.
- ❖ To compare the mechanical properties of the treated (modified) banana fiber with untreated raw banana fiber.

1.2 Significance of the study

The production of eco-friendly natural banana fiber has economic and environmental advantage for the country, for the people who engage themselves in banana plantation and create additional opportunity for the fiber producing plant. Some of the significance is listed below

- ❖ Trunk of matured banana tree will be no more considered as agro waste rather it can be considered as additional asset for the banana farming investors.
- ❖ The production of fiber from such agro wastes use green process so, promote green technology and benefit the country from the clean development mechanism.
- ❖ The fiber can be used directly by textile industry and the fiber manufacturing from trunk of banana creates additional and optional market for fiber demand. Moreover it can be used to fill the gap between supply and demand of cellulosic fiber in textile industry of Ethiopia.
- ❖ The fiber manufactured is easily biodegradable and have advantage in this aspect if widely manufactured and consumed.
- ❖ Promote banana plantation because impose additional income for the banana planters and Help the development of textile industry because the use of natural banana fiber helps them to have low cost as compared synthetic fiber.
- ❖ Help to make fiber glass manufacturing industry to be more profitable because synthetic fiber can be replaced with low cost locally available natural banana fiber and Promote the uses of natural fiber.
- ❖ The result of this thesis work used as base line for other researchers who further study on this area beyond the scope of this thesis.
- ❖ Add knowledge in optimization of banana fiber production parameters. .
- ❖ using leftover banana trunk as raw material in environmental-friendly manner encourage production and use of natural fiber without additional costs and decrease chemical and toxic agents produced in the fiber production process.

- ❖ As production of banana fiber not necessarily need to purchase or grow new plant and using extra chemicals, fertilizers, or pesticides, Utilizing banana fibers will promote sustainable development in the community.
- ❖ Could help us get good quality banana fiber which could be spun into yarns and then could be used in textile and packaging industry
- ❖ To produce banana fiber with good flexibility, better fineness , better moisture regain and tensile Strength
- ❖ To show the basic advantage of using banana fiber and other natural fiber over the synthetic one.

2. LITERATURE REVIEW

2.1 .BASICS OF FIBER

Fibers are thread-like strands extracted from plants, animals, and minerals. Fibers can be spun into yarn. Fibers strands which are at least 100 times longer than their width. Fibers have diverse uses because they are flexible and can be spun into thread, rope, filaments, and string to be used in fabrics. Fibers can be used in composite materials and matted into sheets to make paper or felt. Fibers are classified in two main groups as natural and man made fibers. Our concern in this study is mainly will focus on natural fibers. The attraction in utilizing natural fiber as support in plastics has expanded drastically throughout last few years. This is because modern people start to Concern about their environment. From the ecological viewpoints if natural fibers might be utilized rather than man made synthetic fiber and glass fibers in textile industry and as support in some structural provisions respectively it might be extremely interesting. Natural fibers have numerous points of interest contrasted with glass fiber and other synthetic fiber. Natural fibers are biodegradable and recyclable. They are also renewable crude materials and have generally great strength and stiffness (New World encyclopedia, 2008)

2.2. CLASSIFICATION OF NATURAL FIBER

Natural fibers are hair-like threads obtained directly from plants, animals, and mineral sources. Botanically, a natural fiber is a collection of cells having long length and negligible diameter. They are obtained as continuous filaments or discrete elongated pieces similar to thread. They can be spun or twisted into yarn such as cloth and can be converted into nonwoven fabrics, such as paper or felt. Other examples include wool, jute, silk, hair, fur, hemp, and linen. Natural fibers can be classified on the basis of the origin of source, into three types as:

I. Plant Fibers II. Mineral Fibers III. Animal Fibers

2.2.1. Plant Fibers

Plant fibers are fibers which obtained from parts of plants. Based on the parts of plant from which they are obtained they can be classified as the following types. Seed fibers which are collected from seeds or seed cases. For example, cotton and kapok. Bast fibers are those which are collected from the inner bark or bast surrounding the stem of the plant. These fibers have higher tensile strength than other fibres. As a result they are used for durable yarn, fabric, packaging, and paper. Examples are flax, jute, kenaf, hemp, banana and ramie. Hard fibers are those which are collected from leaves like sisal and agave or from fruit like coir around the hard shell of coconuts. Plant fibre is composed mainly of cellulose and cellulose fibers are most commonly used to make paper and cloth. Cellulose produces long, often highly lustrous fibers when suitably prepared.(textile fashion study,2014)

2.2.2. Mineral Fibers

Mineral fibers are those which are obtained from minerals. These are naturally happening fiber or somewhat changed fiber. A number of fibers exist that are derived from natural mineral sources or are manufactured from inorganic and mineral salts. These fibers are predominantly derivatives of silica (SiO_2) or other metal oxides. In addition, metal fibers (either alone or encapsulated in a suitable organic polymer) can be produced. The common feature of these fibers is their inorganic or metallic composition and tendency to be heat resistant and nonflammable, with the exception of polymer- coated metallic fibers. The following are some common mineral fibers.(fibronamics, 2016)

I. Glass fiber Fibers spun from glass are completely inorganic in nature and possess unique properties that cannot be found in organic textile fibers. Glass fibers have some deficiencies in properties that severely limit their use in apparel.

Glass fibers are used in a number of industrial and aerospace applications and in selected home furnishing uses where heat and environmental stability are of prime importance. Glass fibers are manufactured for industrial and consumer use under a number of names including fiberglas, Beta glass, J-M fiberglass, PPG fiberglass, and Vitron. Glass fibers are strong, but they exhibit poor abrasion resistance, which limits their use in textile structures

for consumer goods. They are used extensively in curtains and draperies, electrical and thermal insulation, tire cord, reinforced plastics etc.(Fitzer, Erich et.al 2008)

II.INORGANIC FIBERS:A series of man-made inorganic fibers other than glass exist that are nonflammable, heat stable amorphous materials useful in industrial fabric constructions, including refractory materials. These inorganic fibers include pure silica, potassium titanates, aluminum borosilicates, and aluminum oxide-zirconium oxide polymers, Most of these fibers have high strength, are less susceptible to chemical attack than glass, and melt above 1000°C. They may be used in higher- temperature applications than possible with most glass fibers.(W.H.Gloor., 2016)

III.ASBESTOS: Asbestos is the name given to several natural minerals (anthophyllite, amphibole, serpentine) which occur in a fibrous crystalline form. The asbestos is initially crushed to open up the fiber mass, followed by carding and spinning to yield fibers of circular cross section 1-30 cm in length. Asbestos is very resistant to heat and burning, to acids and alkalies, and to other chemicals. Although it has low strength, asbestos fiber does not deteriorate in normal usage, and it is not attacked by insects or microorganisms. Asbestos is used in fireproof clothing, conveyor belts, brake linings, gaskets, industrial packings, electrical windings, insulations, and soundproofing materials. Inhaled asbestos fibers have been shown to be a serious health hazard, and it has been removed from the textiles market.(Alleman,James.E and Mossman,Brooke. T, 1997)

2.2.3. Animal Fibers

Animal fibers are natural fibers that consist largely of particular proteins. Instances are silk, hair/fur (including wool) and feathers. The animal fibers used most commonly both in the manufacturing world as well as by the hand spinners are wool from domestic sheep and silk. Unusual fibers such as Angora wool from rabbits and Chiengora from dogs also exist, but are rarely used for mass production. Not all animal fibers have the same properties, and even within a species the fiber is not consistent. Merino is very soft, fine wool, while Cotswold is coarser, and yet both merino and Cotswold are types of sheep. This comparison can be continued on the microscopic level, comparing the diameter and

structure of the fiber. With animal fibers, and natural fibers in general, the individual fibers look different, whereas all synthetic fibers look the same.(Wikipedia free Encyclopidia, 2016)

Silk is a "natural" protein fiber forms which can be woven into textiles. The best-known type of silk is obtained from cocoons made by the larvae of the silkworm *Bombyxmori* reared in captivity. Degummed fibers from *B. mori* are 5-10 μm in diameter. The shimmering appearance for which silk is prized comes from the fibers' triangular prism-like cross-sectional structure which allows silk cloth to refract incoming light at different angles.The length of the silk fiber depends on how it has been prepared. Since the cocoon is made of one strand, if the cocoon is unwound carefully the fibers can be very long.(Mark carwadine,2008 and Mel Schwarth, 2005)

Wool is the fiber derived from the fur of animals of the Caprinae family, principally sheep, but the hair of certain species of other mammals such as goats, alpacas, and rabbits may also be called wool.

Spider silk is the strongest natural fiber known. The strongest dragline silk is five times stronger than steel and three times tougher than Kevlar. It is also highly elastic, the silk of the ogre-faced spider can be stretched six times its original length without damage. As of 2005, there is no synthetic material in production that can match spider silk. But it is actively being sought by the U.S. military for applications such as body armour, parachutes and rope. Genetically engineered goats have been raised to produce spider silk in their milk at a cost of around \$1,500 per gram.(Mark Carwadine, 2008 and Melchwartz,2005)

Alpaca is a fiber that obtained from an alpaca. It is warmer than sheep's wool and lighter in weight. It is soft, fine, glossy, and luxurious. The thickness of quality fiber is between 12-29 micrometers. Most alpaca fiber is white, but it also comes in various shades of brown and black.(Wikipedia free encyclopedia, 2016)

Angora wool or Angora is fiber refers to the down coat produced by the Angora rabbit. There are many types of Angora rabbits - English, French, German and Giant. Angora is prized for its softness, thin fibers of around 12-16 micrometers for quality fiber, and what knitters refer to as a halo (fluffiness). Angora fiber comes in white, black, and various shades of brown.(Angora.Natural fibers 2009. Org, 2013)

Bison-hair Bison is the soft undercoat of the American Bison. The coat of the bison contains two different types of fiber. Main coat is made up of coarse fibers (average 59 micrometers) called guard hairs, and the downy undercoat (average 18.5 micrometers). This undercoat is shed annually and consists of fine, soft fibers which are very warm and protect the animal from harsh winter conditions.(Beula William, 2007)

Cashmere wool is wool obtained from the Cashmere goat. Cashmere is characterized by its luxuriously soft fibers, with high napability and loft. In order for a natural goat fiber to be considered Cashmere, it must be under 18.5 micrometers in diameter and be at least 3.175 centimeters long. It is noted as providing a natural lightweight insulation without bulk. Fibers are highly adaptable and are easily constructed into fine or thick yarns, and light to heavy-weight fabric(Wikipedia free encyclopedia 2017).

Mohair is a silk-like fabric or yarn made from the hair of the Angora goat. It is both durable and resilient. It is notable for its high luster and sheen, and is often used in fiber blends to add these qualities to a textile. Mohair also takes dye exceptionally.(Wikipedia ,animal fiber,2016)

Sheep's wool has two qualities that distinguish it from hair or fur in which it has scales which overlap like shingles on a roof and it is crimped. In some fleeces the wool fibers have more than 20 bends per inch. Wool varies in diameter from below 17 micrometers to over 35 micrometers. The finer the wool, the softer it will be, while coarser grades are more durable and less prone to pilling.(Mark Carwadine, 2008)

Qiviut is the fine underwool of the muskox. Qiviut fibers are long (about 5 to 8 cm), fine (between 15 and 20 micrometers in diameter), and relatively smooth. It is approximately eight times warmer than sheep's wool and does not felt or shrink.

In general, nowadays natural fiber composites application are usually found in building and automotive industry. Natural fiber is considered as a potential reinforce in polymer composites due to its many advantages such as easy availability, low cost, comparable strength properties.(wikipedia ,animal fiber,2009)

2.3 The physical structure of banana

The banana plant is a tree-like perennial herb. It is an herb because the aerial parts of the parent plant die down to the ground after the growing season. It is a perennial because one of the offshoots growing at the base of the plant, the suckers, then takes over. The banana plant, often referred to as a "tree", is a large herb, with succulent, very juicy stem ("pseudostem") which is a cylinder of leaf-petiole sheaths, reaching a height of 20 to 25 ft (6-7.5 m) and arising from a fleshy rhizome or corm. The root system is the means by

which the plant takes up water and nutrients from the soil. The roots are produced by the underground structure called a rhizome. The rhizome is the banana plant's true stem. It is commonly referred to as a corm, and occasionally as a bulb, but the botanically correct term is rhizome.

The part of the plant that looks like a trunk is actually a false stem, called pseudostem. The pseudostem is formed by the tightly packed overlapping leaf sheaths. Even though the pseudostem is very fleshy and consists mostly of water, it is quite sturdy and can support a bunch that weighs 50 kg or more. The leaf is the plant's main photosynthetic organ. Each leaf emerges from the center of the pseudostem as a rolled cylinder. The lapse of time in which a leaf unfolds varies. Under favourable climatic conditions, it takes about seven days, but it can take up to 15 to 20 days under poor conditions. A sucker is a lateral shoot that develops from the rhizome and usually emerges close to the parent plant. The inflorescence is a complex structure that includes the flowers that will develop into fruits. It is supported by the aerial true stem, which is usually called the floral stem. The aerial true stem is produced by the terminal growing point on the rhizome. It grows through the pseudostem and emerges at the top of the plant soon after the last cigar leaf

The female (pistillate) flowers appear first. In cultivated bananas, the ovary develops into a seedless fruit by parthenocarpy (without being pollinated). As it lifts, the bract (a modified leaf) exposes a cluster of female flowers that are normally arranged in two rows. These flowers will develop into a hand of fruit. The number of hands in the bunch depends on the number of female clusters in the inflorescence, and varies depending on the genotype and environmental conditions. In some types the inflorescence remains erect but generally, shortly after opening, it begins to bend downward.

In about one day after the opening of the flower clusters, the male flowers and their bracts are shed, leaving most of the upper stalk naked except at the very tip where there usually remains an unopened bud containing the last-formed of the male flowers. As the young fruits develop from the female flowers, they look like slender green fingers. The bracts are soon shed and the fully grown fruits in each cluster become a "hand" of bananas,

and the stalk droops with the weight until the bunch is upside down. (Anne vezina.et.al 2016)

2.4 Classification of banana

There are five main varieties of banana. Baby or mini which is originally from Malaysia and about half of the size of Cavendish. Manzano , this variety is native to central and south America. Burro(also named as chunky banana)which is stubbier and fatter than Cavendish. Plantain are an entire subset of fruit which are usually cooked. Red are the most delicious type of banana.(<http://www.saveur.com/article>)

2.5 Distribution of banana

Edible bananas originated in the Indo-Malaysian region reaching to northern Australia. They were known only by in the Mediterranean region in the 3rd Century B.C and are believed to have been first carried to Europe in the 10th Century A.D. Early in the 16th Century, Portuguese mariners transported the plant from the West African coast to South America. The types found in cultivation in the Pacific have been traced to eastern Indonesia from where they spread to the Marquesas and by stages to Hawaii.(Scot C. Nelson et. al,2006)

Bananas and plantains are today grown in every humid tropical region and constitute the 4th largest fruit crop of the world, following the grape, citrus fruits and the apple. World production is estimated to be 28 million tons—65% from Latin America, 27 % from Southeast Asia, and 7 % from Africa. One-fifth of the crop is exported to Europe, Canada, the United States and Japan as fresh fruit. India is the leading banana producer in Asia. Indonesia produces over 2 million tons annually, the Philippines about 1/2 million tons, exporting mostly to Japan. Taiwan raises over 1/2 million tons for export. Tropical Africa (principally the Ivory Coast and Somalia) grows nearly 9 million tons of bananas each year and exports large quantities to Europe. Ethiopia produce only about 100,000 tons of banana per annum despite the existence of most suitable environmental condition as Ethiopia is found in tropical region.(Ethiopian Horticulture institute,2014)

2.6. Cultivation of banana

Banana is cultivated in over 120 countries throughout the tropical and subtropical regions of the world. The ten largest banana-producing countries are India, Uganda, Ecuador, Brazil, Colombia, Philippines, China, Indonesia, Democratic republic of Congo, and Costa Rica. About 17% of world's bananas are produced in India. India is the largest producer of Bananas in the world with an estimated annual output of 13.5 million tons. It is cultivated in the tropics; in about 1, 86,000 hectares of land and the fiber yield is around 7.5 lakh tones per annum.

The pseudo stem is thrown as agricultural waste to a great extent .These pseudo stems can be effectively utilized in production of the banana fibers as, annually, about 1.5 million tons of dry banana fibers can be produced from the outer sheath of pseudo stem. With the increasing demand for Banana in International markets, the acreage and production are expected to increase in the coming years, thus generating more of the pseudo stem biomass waste in coming years. (<http://en. Wikipedia. Org/wiki/banana-plantation>)

2.7 USES OF BANANA

According to research done on usefulness of banana by A.K.M . Mohidin ,ManasKantiSaha, Md. Sanower Hossain and AyishaFerdoshi on a scientific journal of Krishi foundation , banana is useful fruity plant which its fruit is used by human and the leaf is a food by animals. The trunk uses can be classified into five. Sap is used for production of liquid fertilizer, nutrient spray and mordant. Fiber is used for production of yarn , fabric,apparel , paper and other biochemical. The central core is used for making candy,pickles and soft. Scutcher is used as vermicompost and fish feed.

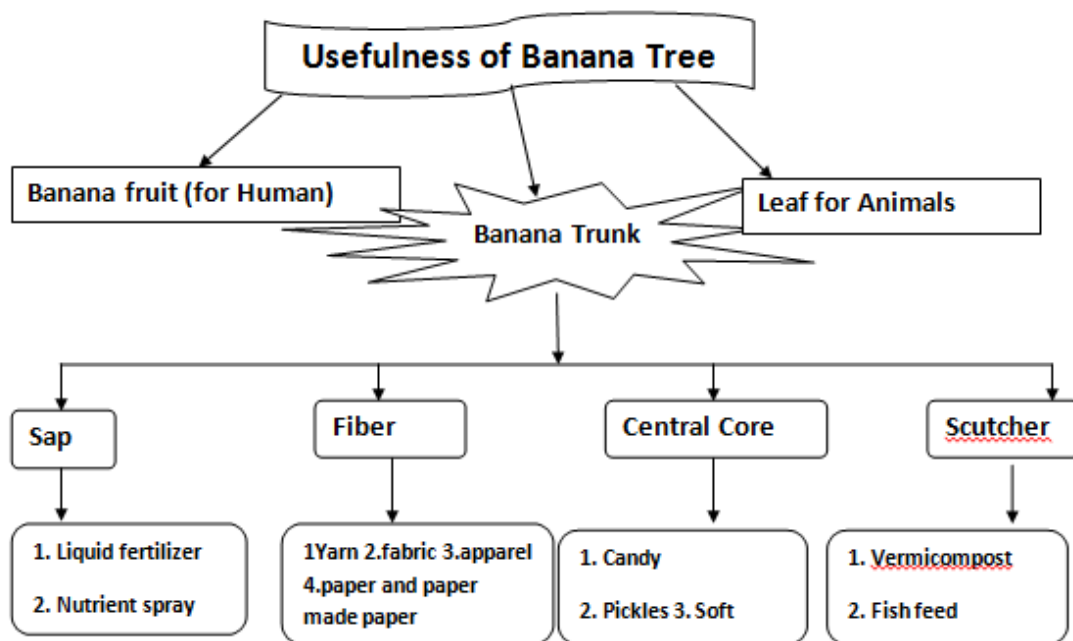


Fig. 2.1 uses of Banana plant

Though fiber extraction is not done on any large scale at present, banana fibres are reported to have been spun on the jute spinning machinery and used hand bags and other fancy articles. Most of the Banana fibers produced today is used for ropes and cordage.

The resistance of the fibre to the sea-water and its natural buoyancy has created a ready market for it in the manufacture of shipping cables. It is also widely used for making power transmission ropes and cordage, wall drilling cables, fishing nets, lines and other types of

cordage. Although banana plants and fibers are available in tropical regions in abundance, their application potential has not been exploited fully.

In recent years, more and more plant fibers were considered to be "environmentally friendly" fiber sources. In the recent past, banana fiber had a very limited application and was primarily used for making items like ropes, mats, and some other composite materials. With the increasing environmental awareness and growing importance of eco-friendly fabrics, banana fiber has also been recognized for all its good qualities and now its application increase in other fields too such as apparel garments and home furnishings. Banana fiber is also used to make fine cushion covers, Neckties, bags, table cloths, curtains etc.

2.8 Fiber Extraction Methods

Natural cellulose fiber are extracted from lignocellulosic by products using bacteria and fungi , mechanical and chemical methods. Retting is also a traditional method to extract fibers which uses bacteria and fungi in the environment to remove pectin ,lignin and other substances. Bacteria such as Bacillus and Clostridium, used in water retting,and fungi such as Rhizomucorpusillus and fusarium lateritium,used in dew retting are found to be most effective in their ability to attack the non cellulosic substance and separate the fibers from core.

Although atmospheric retting provides better quality fibers , it relatively requires relatively longer duration and it is difficult to control. The relatively more common chemical retting methods use alkalis, mild acids and enzymes for fiber extraction.

Sodium hydroxide is the most commonly used chemical for fiber extraction. acids such as sulfuric acid and oxalic acid in combination with a detergent is also used for fiber extraction. Chemical concentration, temperature and the duration of treatment are the main factor for the quality of extracted fiber. Banana fiber can be extracted in different ways.

2.8.1 MANUAL METHOD

Banana fiber can be extracted from waste stalk, leaf and roots of banana plant. But most abundant of banana fiber is obtained from the surface near to the outer sheath of the stem. It can be peeled off easily using ribbons or hand. It is the simple stripping process in which trunks are pulled apart and sheath is undressed. Finally the fiber is obtained by removing pulpy part using ribbons.

2.8.2 CHEMICAL EXTRACTION METHOD

For chemical extraction, alkali treatment is used. The alkali NaOH, sulfuric acid, hydrogen peroxide, protease, pectinase, and sodium citrate are used. The main disadvantage of chemical extraction is the time taken in a whole process. To produce a good quality fiber it can take 35-40 days. There is also a lot of wastage in the process.

2.8.3 MECHANICAL EXTRACTION METHOD

It is extraction of fiber using simple machine consisting of single roller which rolls on a fixed support. The roller is provided with horizontal stainless steel blades with blunt edges. Mechanical extraction using simple machine can reduce labor work and it can increase fiber production by 20-25 times as compared to manual process. The fully grown plant is used to extract the fibers. Brown-green skin is thrown away retaining the white portion which will be processed into knotted fibers. Once dried, the fibers are ready for knotting. Each fiber is separated according to sizes and grouped accordingly.

2.9. Mechanical Properties of Banana Fiber

The amount of cellulose and non-cellulosic constituent constituents in a fiber determine the structure and properties and influence its crystallinity and moisture regain. All properties such as density, electrical resistivity, tensile strength modulus, moisture regain and crystallinity is related to the composition and internal structure of the fiber.

The mechanical properties of natural fibers are influenced by the composition, structure and the number of defects in a fiber. Here are the summary of the physical and mechanical properties of the banana fiber extracted mechanically.

Table 2.1 properties of banana fiber (Ravi Bhatnagar et.al, 2015)

Diameter (micrometer)	80-250
Length(mm)	1000-5000
Moisture content(%)	60
Aspect ratio(l/d)	150
Tensile strength(MPa)	529-914
Specific tensile strength(MPa)	392-677
Young's modulus(GPa)	27-32
Specific young's modulus(GPa)	20-24
Failure strain(%)	1-3
Density	750-950

Table 2.2 A physical properties of banana fibers.(Gupta et .al,1972)

Physical properties	result
Single fiber tenacity(gf/tex)	46-64
Single fiber extension at break(%)	2.9-4.3
Fiber bundle tenacity(gf/tex)	24-30
True density(g/cm ³)	1.31-1.33
Apparent density(g/cm ³)	62-86
Flexural rigidity(33-40)	33-40
Length of raw fiber(cm)	34-85

Moisture regain at 65% r.h	14-15.2
Fiber porosity (%)	35-53

Some results indicate that variation exists in both structure and properties of fibers from different regions along the length and across the thickness of the trunk. Banana fiber is a natural leaf fiber. It has its own physical and chemical characteristics and many other properties that make it a fine quality fiber. The appearance of banana fiber is similar to that of bamboo fiber and ramie fiber and its chemical composition of banana fiber is cellulose, hemicelluloses. It is a strong fiber with smaller elongation and shiny appearance depending upon the extraction.

2.10. Chemical properties of banana fiber

Banana fiber properties can be affected by various chemicals. The following table shows some of the scientifically known effect of some chemical and reagent.

Table 2.3 chemical properties of banana fiber

SOLVENT	REACTION
Dilute NaOH(1%)	No reaction even on heating
Conc. NaOH(20%)	No reaction on cold but on heating and boiling for Several minute fibers swell.
Dilute and conc. HCl	No effect
Dilute HNO ₃	No effect
Conc. HNO ₃	On heating disintegration of fiber and changes to yellow

Dilute H ₂ SO ₄	On heating slight swelling and disintegration of fiber
Conc.H ₂ SO ₄	Dissolves fiber completely
Phenol	No effect
Acetic acid	Fiber become soft
Acetone	No effect
REAGENT	COLOR CHANGE
Zinc chloride and Iodine reagent	Golden yellow
Para- nitro aniline reagent	Bright orange
Potassium permanganate	Pink
Meliorate green	Green
Iodine and Sulphuric acid reagent	yellow

2.11. Chemical composition of banana fiber

The cellulose is the main constituent of plant fibers followed by hemicellulose and lignin interchangeably and pectin respectively. Cellulose is also reinforcement for lignin, hemicellulose and pectin. Here is a summary table given below.

Table 2.4 chemical composition of banana fiber(Ravi Bhatnagar et al, 2015)

Cellulose (%)	60-65
Hemi cellulose (%)	6-19
Pectin (%)	3-5
Ash (%)	1-3
Lignin (%)	5-10

Extractives (%)	3-6
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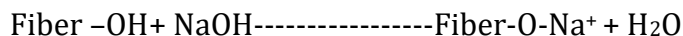
2.13. Chemical Treatment of banana fiber

The most common chemicals for treating banana fiber are alkalis, most well-known alkali used is NaOH. NaOH reduces roughness of fiber and produce a good quality of fiber. In addition , sulphuric acid, hydrogen peroxide, sodium silicate , , acetic acid and sodium citrate are among the chemical used a during chemical treatment of fiber. protease , pectinase , and other type of enzyme are used in biological treatment method. As lubricant cotton seed oil , aloe vera oil ,castor oil, sodium silicate , Epsom salt , soap, sodium lauryl sulphate and other oil can be used.

2.13.1. ALKALI TREATMENT

Alkali treatment the most common and well known type of treatment process in banana and other natural fiber. During alkali treatment (NaOH), the most important factors are concentration of alkali, temperature at which fiber is treated with alkali and time length for which the fiber treated with alkali.

So in general these factors during alkali treatment are considered as the most crucial in influencing the type and quality of fiber obtained. The possible reaction during alkali treatment is the following.(Han,1998 and Suhaib A. Sheik)



The treated banana fiber with sodium hydroxide is found to have darker color.

2.13.2 TREATMENT WITH PEROXIDE

Banana fiber treated with 3%-5% hydrogen peroxide has a good appearance as compared with non-treated one. Hydrogen peroxide is the most common type of a bleaching agent which can be used on banana plant fiber. In this study 5% of hydrogen peroxide was used for bleaching purpose.

2.13.3. TREATMENT WITH SILICONE SOFTENER, CASTOR OIL AND SOAP

Sodium silicate (10%-20%) is one of the most frequently used lubricant of banana fiber. Banana fiber treated with sodium silicate has more flexibility and moisture regain as compared with the non treated one. In nature freshly extracted banana fiber is stiff and lack softness and flexibility force us threat with different softeners. So the spinning properties of the banana fiber should be improved by treating with common softeners such as silicon softner, castor oil, soap and cotton seed oil should be applied. In some experiment a mixture of water silicon softner (10%) castor oil (10%), soap (10%) and acetic acid (10%) was used. There will be a weight gain depending on the structure of fiber. The silicate coated banana fiber results in more tensile strength as compared to untreated one due to silicate stiffness.

In the textile industries, silicones are used in all stages of the process, on the fiber during production, on the fabric or directly on the finished goods. Silicones are applied from different delivery systems to provide various benefits like lubrication, softening, foam control or hydrophobic coatings. Castor oil, soap and acetic acid are also plays the most important role in lubricating banana fiber and improving the process ability for further uses. Softening is considered to come from the siloxane backbone flexibility and the freedom of rotation along the Si-O bonds.

2.14. Trends of using natural fiber in Ethiopia

In Ethiopia there is a trend of using false banana fiber for the production of ropes, spectacles, decorating material and for gypsum work tremendously. But there is also a use of sisal fiber in some part of Ethiopia for the same purpose stated above even if it is not in the scale that false banana fiber is used. Unfortunately even if there a considerable amount banana cultivation in Ethiopia, there is no observable trend of using a banana fiber. banana trunk is considered as useless in Ethiopian rural area farmers who are cultivating banana in small scale and Ethiopian local farmers have no idea of using banana trunk to extract natural fiber. It is hard to find literature studied utilizing banana fiber in context of

Ethiopia. Traditional farmers and even commercial large scale cultivators are producing banana hoping only for its fruit.

2.15. Studies related to banana fiber in Ethiopia

In Ethiopia there is no considerable research done on the production, treatment, and characterization and production optimization of banana fiber. However in Ethiopia there is a huge production of banana plant especially in SNNP region at commercial level. The only research that can be stated as a research on plant fiber may be a research done by AlhayatGetuTemesgen and OmprakashSahu of wollo university on processability enhancement of false banana fiber in the year 2014.

2.16. The studies related to banana fiber worldwide

Marwan Mostafa and NasimUddin(2015) study the effect of banana fibers on compressive and flexural strength of the compressed earth blocks and they obtained that banana reinforced block has superior property than other fiber and straw reinforced block. Vamilapaul (Durban university of technology 2015) studied synthesis and characterization of a biocomposite derived from banana plants.

BandiStruthi and Chand Badshah(2015) studied the use of banana fibers as fillers in the rubber industry as a new trend. It is observed that the tensile strength of banana fiber reinforced polyester composite is increased by 90% as compared to virgin polyester.

American journal of engineering (2015) study shows that a treated banana fiber produce high tensile strength than untreated one. Preethip and Balakrishma Murthy G. (2013) studied the physical and chemical properties of banana fiber. The international journal of engineering and science (2013) Studies on extraction of Naturally occurring banana fiber. The fiber was treated with 0.0M, 0.01M, 0.05M and 0.1M of NaOH and PH of a solution was covered 6.71 TO 7.60 and the optimum PH was found to be 7.39. It also found that in retting method of banana extraction the higher the concentration of the NaOH the longer

the number of days it Takes the retting solution at optimum PH. And it justify that a fiber yield of 0.25%-0.55% can be obtained.

Al-Hayat Getu Temesgen and Omprakash Sahu (Wollo University, 2013) studied properties of treated and untreated false banana fiber. They observe that treated false banana fiber has superior property than untreated one. Manish kumar and Deepak kumar (2011) studied the comparative study of pulping of banana stem mechanically and biologically.

Vasatwiki (2008) discussed about the cultivation and properties of banana fibers. According to him banana fiber has long been a source of fiber for high quality textile. The banana stem produces fibers of varying degrees of softness yielding yarns and textiles with differing qualities for specific uses.

Desai (2008) reported about conventional textile in indian banana fibers. The banana fibers were reported to be elegant and highly versatile. Bryan lee (2007) studied the use of banana stain to decorate fabrics or for aesthetic purpose .

Mitra et.al (2007) investigated the use of natural ligno-cellulosic fibers and their blends for textile application. It has been observed that ligno cellulosic long vegetable fiber such as jute , banana, ramie , sisal etc have wide textile uses.

Walker (2006) suggested about envelopes made from banana are the latest green products to be launched by UK company the Consortium. Behara and coworkers (2006) had carried out a comparative assessment of low stress mechanical properties and sewability of cotton and cotton-banana union fabric . It is found that the fabric allows full limit of performance of high speed sewing machinery without the fabric suffering perceptible mechanical degradation.

Maleque and co workers (2006) had discussed about the mechanical properties of pseudostem banana fiber reinforced epoxy composite. It is found that the banana fiber composite has better strengths than wood composite.

On the article by Tree Hugger (2005) on papyrus , Australia makes a banana paper, explains about a technology that turns banana waste into a paper . Papyrus make a banana paper using economical process that uses no chemical, and able to produce a water proof and about 3000 times stronger than wood pulp paper.

Bahra et.al(2001) studied on Hand value of cotton –banana union fabric. Two samples were produced for study. 100% cotton fabric and cotton-banana fabric where cotton yarn were used as wrap and banana filament as weft. It was concluded that banana fiber was stiff filament, coarser, thicker, stronger and possess high moisture regain than cotton fiber. The cotton –banana union fabric is less extensible , less compressible with high bending modulus and flexural rigidity than pure cotton fabric. The cotton banana union fabric is stronger than cotton fabric weft(banana fiber) direction..

According to national research centre for banana of india (NRCB),a research is already carried out that their country very soon flooded with an array of textile and garment product made from banana fiber.According to the research done by Moi university department of manufacturing, industrial and textile engineering, in the study of the effect of degumming condition on deformation behavior of banana (*Musa accuminata*) pseudostem fibers . It is observed that an increase in concentration at constant treatment time and temperature had degrading effect on the fibers breaking tenacity and breaking extension.

Degumming of banana fiber at 1M at 90°C for 90 minutes have a good result and a good compromise between breaking tenacity and breaking extension.

Bilba et al. determined the chemical composition of banana pseudo by elemental analysis. The results were found as cellulose 31-35%, hemicellulose 14-17% and lignin is 15-16%. As the article on a mechanical properties of natural fiber (banana, coir, sisal) polymer composite by ass. Professor Adhiyamaan and professor Sona it is observed that it is possible to fabricate the best natural composite using banana fiber.

E.U Akubeze et al.(2015) studied the banana fibers obtained using natural and microbial retting techniques. The physico-mechanical properties of the fibers were determined according to ASTM standard for textile fibers, zippers, yarns and fabrics. The tensile strength 380-650 MPa and 309.86- 450.70MPa, elongation break 1.7%-2.7% and 2.5 -4.6%, young's modulus 24.5-36.0GPa and 12.99-25.89GPa for natural and microbial fibers respectively.

According to an article on the journal of material on production of banana fiber yarns for technical textile reinforced composite, it is observed that the banana containing yarn has higher tenacity than flax containing yarn and it is more homogeneous.

Smart Mukhopadhyay, Ph.D university of Minho (Portugal) study the variability and fracture behavior of banana fiber. It is found that the variation of diameter starting from 0.08mm to 0.32mm. with the most frequent value of 0.17mm (26%) by taking hundred single fiber randomly from a sample. The sample diameter follows the normal distribution curve.

M. Thiruchitrambalam et al. (2009) study about improving the mechanical properties of banana/kenaf polyester hybrid using sodium lauryl sulphate treatment. The fibers are treated with 10% of sodium hydroxide and 10% Sodium lauryl sulphate for 30 minutes. It is found that alkali treatment has improved the mechanical property of the composite. It is also found that sodium lauryl sulphate treatment improved the mechanical property than sodium hydroxide.

Samrat Mukhopadhyay et al. studied about the various diameters of banana fibers. Hundred fibers were chosen at random from the collection of banana fibers. There was a wide range of variation of diameter starting from 0.08 mm to 0.32 mm. Based on a class interval of 0.029 mm, which establishes that the standard deviation has decreased with an increase of diameter of the fibers meaning that coarser fibers were more regular in nature.

V. Nilza G. Justiz-Smith et al. study on Potential of Jamaican banana, coconut coir and bagasse fibers as composite materials. It presents an evaluation of the alternative use of three Jamaican natural cellulosic fibers for the design and manufacturing of composite materials. The natural cellulosic fibers under investigation were bagasse from sugarcane, banana trunk from the banana plant, and coconut coir from the coconut husk. The banana fiber exhibited the highest ash, carbon and cellulose content, hardness and tensile strength, while coconut the highest lignin content.

Lina Herrera-Estrada et al. investigated that banana fiber reinforced composite material with a thermoset, suitable for automotive and transportation industry application. Fiber surface chemical modifications and treatments were studied along the processing conditions for epoxy and eco-polyester banana fiber composites. Flexural tests show that

banana fibre eco-polyester composites have a higher flexural strength and modulus due to improved fibre matrix interaction.

The European Union tailored study (2014) future alternative material revealed that banana fiber as one of the very promising substitute of synthetic and other natural fiber such as cotton with high demand. According to this study, Ethiopia is considered as one of the very promising country in production of banana fiber based on main market drivers, buyer's requirements, trade channels , segments and favorable Environmental condition.

According to Ethiopian Horticulture Institute(2014), the current annual production of banana is estimated more than 100,000 ton. It can easily guessed that how much waste can be generated because the banana trunk is considered as waste after harvest every 8-12 month.

3. MATERIALS AND METHODS

3.1 DESCRIPTION OF STUDY AREA

The study was focused on indigenous type of banana which is widely distributed in most part of Ethiopia. The sample banana trunk was collected from Oromia region, westshewa zone ,around Guder where enormous amount of local species banana grown. Guder is a town located in the western part at 92km distance from Addis Ababa. Some farmers in this area and even the town dwellers in the coastal reagion produce banana plants. In this area about one farmer may have up to quarter of hektar covered with banana plantation. Most of the town dwellers also have banana plant in their garden.

3.2 SAMPLE COLLECTION AND PREPARATION

The sample was produced from indigenous type of musa variety grown commonly in this area sing manual method. The trunk was cut and freshly and each layers are separated. Then then internal part of each individual layer is removed using iron ribbon. Then the fiber is extreacted carefully using ribbon and analysed for its maximum yied. Then the fiber is transported for analysis to south west academy laboratory for treatment and then to Ethiopian textile industry development institute for further treatment, standardize, and mechanical property test using tight plastic bags to avoid any contamination with external factors during transportation.

3.3 MATERIALS, EQUIPMENT AND REAGENTS

The materials and equipment used for the study are:

- ❖ Banana fiber
- ❖ tensile test machine (TEXTECHNO STATIMAT ME+ ISO2062-500)
- ❖ 30% hydrogen peroxide and 99.9% sodium hydroxide pellets
- ❖ sodium lauryl sulfate and 30% sodium silicate softener
- ❖ pure castor oil, 99.9% acetic acid and silicon softener
- ❖ linear density measuring device (ASTM-D 6612)
- ❖ Microwave oven
- ❖ Concentrated sulfuric acid, bakery, stirrer, distilled water and thermometer.

3.4. PROCEDURES AND METHODS

3.4.1 Methods of preparing banana fiber

The indigenous type of banana which is widely distributed and widely cultivated in small scale by farmers in Guder area is freshly cut and each layer are separated. Then immediately fiber is extracted manually by scraping away the plant tissue using iron ribbon till fibers were fully separated using fresh method as shown in figure bellow. The mass of the single layer is determined and fiber is being extracted to determine the possible yield.



Fig.2.2extraction of banana fiber using manual method using iron ribbon

The yield percentage of extracted fiber was calculated using the formula:

$$\begin{aligned}
 \text{Yield \%} &= \frac{\text{Weight of the Extracted Fiber}}{\text{Plant Part Used For Extraction}} \times 100 \\
 &= \frac{46\text{gram}}{230\text{gram}} \times 100 \dots\dots\dots \text{Equation 3.1} \\
 &= 20\%
 \end{aligned}$$

3.4.2 Washing sample with dilute acid

The extracted fiber was transported to south west academy laboratory which is found in Nifas silk lafto sub city around Jamo area for further treatment. 5gram of sample was washed with 0.01M solution of 200 ml sulphuric acid and rinsed with distilled water before the treatment to remove any form of impurities and dusts which may be attached during production and transportation using plastic bags.

3.4.3 .Methods of preparing sample

Washed and purified raw sample was treated with sodium hydroxide (NaOH). In each experiment 5gram of sample was taken and treated with various concentration(0.1M, 0.3 and 0.5M) of 200 ml sodium hydroxide at different treatment temperature (30⁰c,60⁰c and90⁰c) and at different treatment time(30min,45min and 60min) in oven.

3.4.4 Methods of Bleaching of sample with hydrogen peroxide

Banana fiber treated at different concentration of sodium hydroxide different treatment duration of time at separate temperature is washed individually with distilled water and allowed to dry in atmosphere for 48 hrs. Then after 48 hour of exposure to atmosphere

and allowed to dry, the fiber is treated with 5% of H_2O_2 for 72 hours at room temperature. Then washed with distilled water and exposed to atmosphere again to dry and get ready for further treatment.

3.4.5 Treatment of sample with lubricants.

Bleached and dried fiber like banana fiber lack flexibility and softness. Therefore the fiber was treated with different softeners such as silicon softener, castor oil, soap and acetic acid was applied. In this experiment a mixture of water silicon softener (10%) castor oil (10%), soap (10%) and acetic acid (10%) was used.

3.4.6 Design of experiment

The design of experiment was used according to the standard method for scientific research. Three factors with three levels full factorial design was used in experiment to produce banana fiber at different process parameters. The factors are temperature, concentration and time and tensile strength is selected as a response variable. The properties of fiber quality are length, strength, micronaire, length uniformity, color grade and leaf grade. Fiber strength is translated directly to yarn strength. Producing stronger yarns allow faster and more efficient processing. Moreover fiber strength (tensile strength) is selected as a response variable because it is highly affected by treatment process. It is the most variety dependent property as we are studying the fiber obtained from Ethiopian most widely cultivated species of banana. The sample was treated with 0.1M, 0.3M, and 0.5M of sodium hydroxide at 30°C, 60°C, and 90°C for 30 min, 45min and 60min. Therefore the 3^k design, three factors with three levels with one response variable which is mechanical properties (tensile test) of fiber was done.

Table 3.1 process parameters levels and response variable blocking and randomization table

STN	GROUP	RUN NUMBER	TIME(MIN)	CONC(M)	TEMP(°C)	TENSILE STRENGTH
4	1	1	-1	-1	0	
7	1	2	-1	-1	+1	
6	1	3	-1	+1	0	
9	1	4	-1	+1	+1	
5	1	5	-1	0	0	
3	1	6	-1	+1	-1	
2	1	7	-1	0	-1	
1	1	8	-1	-1	-1	
8	1	9	-1	0	+1	
27	2	10	+1	+1	+1	
22	2	11	+1	-1	0	
21	2	12	+1	+1	-1	
25	2	13	+1	-1	+1	
23	2	14	+1	0	0	
19	2	15	+1	-1	-1	
26	2	16	+1	0	+1	
20	2	17	+1	0	-1	
24	2	18	+1	+1	0	
10	3	19	0	-1	-1	
16	3	20	0	-1	+1	
15	3	21	0	+1	0	
14	3	22	0	0	0	
13	3	23	0	-1	0	
12	3	24	0	+1	-1	
17	3	25	0	0	+1	
11	3	26	0	0	-1	
18	3	27	0	+1	+1	

3.4.7. ANALYSIS OF SAMPLE DATA

The sample collected was washed with distilled water then treated with sodium hydroxide under different condition of temperature, concentration of sodium hydroxide and time. 5g of the sample produced was treated with 0.1M, 0.3M, and 0.5M solution of 200ml sodium hydroxide at a temperature of 30°C, 60°C and 90°C for duration of 30min, 45min, and 60min. Then it is bleached with 5% hydrogen peroxide as shown below.



Fig 3.1 *Banana fiber after soda treatment and bleaching with peroxide*

3.4.8. Material liquor ratio

For each sample in experiment five gram of banana fiber is immersed in 200 ml of total liquid volume for all concentration of sodium hydroxide with all time of treatment and for all type of temperature. In this experiment the same material liquor ratio is used for bleaching and lubrication.

3.4.9. Measurement of linear density

The linear density of the untreated and treated fiber was determined using standard linear density measuring device according to ASTM D-6622. 10 samples of 20 cm in length of treated and untreated sample 200 cm in sum put in linear density measuring device. Accordingly the linear density of treated and untreated banana fiber is found to be 9.24Ne and 26.80Ne respectively. The linear density of treated banana fiber is far greater than untreated one.

3.4.10 Analysis of mechanical properties of banana fiber

A mechanical property of banana fiber is determined using standard method of testing the mechanical properties of material. The mechanical properties under investigation are elongation, maximum force, work to break, tenacity and time to break. The sample was grouped based on the length of treatment time length as a main factor and all the 27 sample strain was determined from the crosshead movement. Testing was made according to ASTM D 3822-07. The test was done using totally computerized testing machine (TEXTECHNO STATIMAT ME+ ISO2062-200) using load cell of 100N ,gauge

length 100mm with test speed of 500mm/min. For each run 10 sample of fiber is measured for mechanical properties and the average of the 10 sample single fiber test was taken as a result for specific sample.



Fig 3.2 sample tensile strength test.

4. RESULT AND DISCUSSION.

4.1 RESULT

4.1.1 EFFECT TREATMENT OF SAMPLE WITH SODIUM HYDROXIDE

Alkalization was made at the temperature 30⁰c, 60⁰c and 90⁰c with 0.1M, 0.3M and 0.5M of sodium hydroxide. It is known that quality of fiber affected considerably by the type of surface treatment which it undergo. The sodium hydroxide opens up the cellulose structure allowing the hydroxyl groups to get ready for the reactions. During washing with distilled water after treatment with sodium hydroxide, the wax, cuticle layer and part of lignin and hemicellulose were removed. Therefore fiber treatment resulted in the increase in mechanical properties of the fiber because it makes ready for auxiliary treatment.

The alkali treatment process has some critical parameters like Alkali concentration, Treatment duration and temperature(David N Githinji et.al ,2015). In this observed that concentration solution and treatment duration plays major role on the properties of banana fiber. It is also observed that there is a positive effect cited when the concentration increases up to 0.3M at constant temperature and duration of time. Beyond this concentration it is observed that the mechanical properties of treated banana fiber starts to degrade. This could be attributed to removal of more pectin and lignin and hydrolysis decrease the molecular length which affect the extensibility and other mechanical property. Many studies were carried out to improve the properties of the fibers in composites. Mwaikambo et al 2002 studied the alkalization or

acetylation of plant fiber resulting in the changes of the surface topography of the fibers and their crystallographic structure. David N Githinji et.al ,2015 studies effect of degumming condition on the deformation behavior banana fiber in which nearly comparable result was obtained.

4.1.2. EFFECT OF SAMPLE TREATED WITH PEROXIDE

Bleaching is the procedure of improving the whiteness of textile material, with or without the removal of natural coloring matter and extraneous Substances. Hydrogen peroxide is the most common powerful bleaching agent which is used in decolorizing color of natural fiber(Inklet, 1995) so in this study bleaching of the banana fiber was done by putting 5gram of treated banana fiber in 200 ml of 5% (Melicia Cintia Galdeno and Maria Victoria Eiras Grossman, 2005). 5% of hydrogenperoxide was used because of it is the most suitable concentration to bleach banana fiber when it is used as exclusive bleach.(Amita Doshi, 2016) of hydrogen peroxide for 72 hours at room temperature. After the treatment the fiber become white.

4.1.3. SAMPLE TREATED WITH SILICON SOFTENERS ACETIC ACID, SOAP AND CASTOR OIL

In nature freshly extracted banana fiber and even sodium hydroxide treated banana fiber is stiff and lack softness and flexibility force us threat with different softeners. So the spinning properties of the banana fiber should be improved by treating with common softeners such as silicon softener, castor oil, soap and cotton seed oil should be applied.

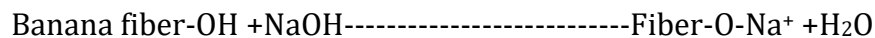
In this experiment a mixture of water silicon softener (10%) castor oil (10%) ,soap(10%) and acetic acid (10%) was used. It is observed that the lubricated banana fiber has

superior mechanical property, softness, flexibility and moisture regain than untreated raw banana fiber(Alhayat Getu temesgen, 2014).

It is observed that a banana fiber treated with acetic acid has better moisture regain, superior flexibility, and better softness. 200ml of 10% acetic acid was used to treat 5 gram of fiber treated which is already treated with various concentration of NaOH. Treatment for 72hrs in acetic acid produce a good quality soft banana fiber with better spinnability properties.

4.1.4. Expected chemical modification of banana fiber

Banana fiber treated chemically expected to have superior property in tensile strength, moisture regain , softness and flexibility. This is because of certain reaction takes place on the surface of lignocellulosic fiber like banana. The possible reaction of banana fiber treated with sodium hydroxide is:



It can be seen that significant difference in the tensile strength between the alkali-treated and the untreated fiber. The tensile strength of the banana fiber when using the alkali usually greater because after alkali treatment, most of the impurities like lignin and pectin that covered the fiber surface were removed. The higher elongation at break for the alkali-treated banana fiber indicates that the removal of the lignin and pectin improved the elasticity of the banana fiber.

4.1.6. EFFECT OF ALKALI CONCENTRATION

Generally treating banana fiber with alkali produce good quality banana fiber .it is observed that the fineness of banana fiber increases as the concentration of sodium hydroxide increases. The tensile strength of the fiber increase first and decrease then as the concentration of hydroxide increases. Here is a computer reading after the tensile test was

done using ASTM D3822-07 TEXTECHNO STATIMAT ME+(ISO2062-500). The effect of concentration on tensile test was determined by keeping the two other parameter constant.

4.1.6.1 Percent elongation

The percent elongation of treated banana fiber is found to gradually increases at constant temperature and treatment time. The percent elongation of banana fiber treated for 60 minutes at temperature of 30°C for 0.1M, 0.3M, and 0.5M . It is found that the percent elongation decreases from 1.83% ,1.54% to 0.88%.

4.1.6.2. Maximum force

The maximum force of treated banana fiber gradually increases as the concentration of sodium hydroxide increases . maximum force for banana fiber treated for 60 minute at a temperature of 30°C at the concentration of 0.1M, 0.3M, and 0.5M is found to decrease gradually from 1.8N 1.67N to 1.57N

4.1.6.3 .Work to break

The work to break of treated banana fiber also gradually increases as the concentration of sodium hydroxide increases. The mechanical properties of banana fiber treated at various concentration keeping other parameters constant. . the work to break for banana fiber treated for 60 minute at a temperature of 30°C at the concentration of 0.1M, 0.3M, and 0.5M is found to decrease gradually from 81.17CN*CM, 32.16CN*CM to 29.56CN*CM.

4.1.6.4. Tenacity

The tenacity of treated banana fiber also gradually increases as the concentration of sodium hydroxide increases. The mechanical properties of banana fiber treated at various concentration keeping other parameters constant. The table 4.1 shows a result obtained when banana fiber treated for 60 minutes at temperature of 30°C for 0.1M, 0.3M, and 0.5M. It is found that the tenacity decreases from 24.62CN/TEX through 8.29CN/TEX to 7.76CN/TEX. This could be attributed that at higher concentration of sodium hydroxide more pectin and lignin can be removed as well as hydrolysis of polymer results in to shorter length polymer which finally results in decrease in mechanical property of fiber.

Table 4.1.5 Effect of sodium hydroxide concentration on mechanical property of banana fiber.

Treatment Type	Elongation (at F max)	Maximum Force	Work to Break	Tenacity	Linear Density	Time to Break
Untreated (virgin banana)	1.04%	2.04N	72.35CN*CM	3.11CN/TEX	9.00Ne	0.63Sec
Banana fiber treated at 0.5M NaOH	0.88%	1.71N	29.56CN*CM	7.76CN/TEX	26.80Ne	0.21Sec
Banana fiber treated at 0.3M	1.50%	1.67N	27.75CN*CM	26.80CN/TEX	26.80Ne	0.21Sec

NaOH						
Banana fiber treated at 0.1M NaOH	1.54%	5.42N	81.17CN*CM	24.17CN/TEX	26.80Ne	0.18Sec

In general the same result has been observed for other temperature and treatment time. The whole data can be referred from the appendix of the thesis. So generally it can be observed that the mechanical properties of banana fiber increases to certain limit when treated with alkali(sodium hydroxide) and then decreases as the concentration of the alkali decreases. This can be observed by comparing virgin banana mechanical properties with banana treated with 0.1M of sodium hydroxide. In this case there is a general increase in mechanical properties. But when we compare the mechanical properties of virgin banana fiber with banana fiber treated with 0.5M of sodium hydroxide at constant temperature and treatment time there is a general decrease in mechanical properties of the fiber. This indicates that the concentration of sodium hydroxide should be optimized to obtain the banana fiber with better mechanical properties.

4.1.7 EFFECT OF TEMPERATURE DURING ALKALI TREATMENT

The effect of temperature is analyzed by keeping the concentration of alkali and treatment time constant. As the temperature of alkali treatment increases the tensile strength of the fiber increases first and then gradually decreases. It is already found that treating the banana fiber with higher concentration of NaOH tends to decrease the mechanical strength of banana fiber while increasing the fineness and softness of the fiber.

Now it is a time to find out the consequence of increasing temperature at constant concentration and treatment time. Here is a mechanical property of fiber obtained by treating banana fiber at 30⁰c,60⁰c and90⁰c keeping concentration at 0.1M NaOH and treatment time at 30 min

Table 4.1 Effect of treatment temperature on mechanical property of banana fiber.

Treatment Type	Elongation (at F max)	Maximum Force	Work to Break	Tenacity	Linear Density	Time to Break
Untreated (virgin banana)	1.04%	2.04N	72.35CN*CM	3.11CN/TEX	9.00Ne	0.63Sec
Banana fiber treated at 300c NaOH	1.54%	5.42N	81.17CN*CM	24.62CN/TEX	26.80Ne	0.18Sec
Banana fiber treated at 600c NaOH	1.55%	2.30N	55.48CN*CM	12.90CN/TEX	26.80Ne	0.19Sec
Banana fiber treated at 900c NaOH	1.57%	1.67N	27.75CN*CM	7.57CN/TEX	26.80Ne	0.21Sec

From the result displayed on the above table it can easily be observed that there is a gradual and very slow increase in mechanical property of banana fiber. The same result was observed for other concentration and time of treatment. For example it can be observed that the elongation at maximum force of banana fiber changes from 1.54% through 1.55% to 1.57% for a change in temperature from 30⁰c through 60⁰c to 90⁰c.

Thus it can be easily understood that the mechanical properties of the banana fiber is less affected by change in temperature as compared with the two other parameters under investigation in this thesis.

4.1.10 EFFECT OF TREATMENT TIME

The effect of time of treatment was studied keeping the concentration and temperature constant. Here is a result directly reprinted from computer reading as tensile test was done on a fiber treated with 0.3M of sodium hydroxide at a temperature of 90⁰c for 30min, 30min and 60min. From the data it is observed that as the time of treatment with sodium hydroxide increases by keeping concentration and temperature constant most of the crucial mechanical properties of banana fiber is increasing. softness and elasticity of the banana fiber also increases. The following table shows the result

Table 4.1 Effect of treatment time on mechanical property of banana fiber.

Treatment Type	Elongation (at F max)	Maximum Force	Work to Break	Tenacity	Linear Density	Time to Break
Untreated (virgin banana)	1.04%	2.04N	72.35CN*CM	3.11CN/TEX	9.00Ne	0.63Sec
Banana fiber treated for 60min	6.06%	1.30N	172.48CN*CM	5.90CN/TEX	26.80Ne	3.63Sec
Banana fiber treated for 45min	3.06%	1.50N	55.48CN*CM	6.90CN/TEX	26.80Ne	1.86Sec
Banana fiber treated for 30min	1.83%	1.81N	32.16CN*CM	8.20CN/TEX	26.80Ne	0.33Sec

From above tables it can be observed that the mechanical properties of banana fiber is highly affected by treatment time. In above table as the time of treatment increase from 30 min through 45min to 60min the elongation at at maximum force and other mechanical properties are highly affected.

The elongation at maximum force changes from 1.83% through 3.06% to 6.06% for a time of treatment 30min ,45min and 60min respectively. Thus it can be easily observed that treatment time is the most important factor needs to be optimized in banana fiber treatment.

**4.1.12. COMPARATIVE OVERVIEW OF TREATED AND UNTREATED
BANANA FIBER**

Treatment Type	Elongation (at F max)	Maximum Force	Work to Break	Tenacity	Linear Density	Time to Break
Untreated (virgin banana)	1.04%	2.04N	72.35CN*CM	3.11CN/TEX	9.00Ne	0.63Sec
Banana fiber treated for 60min	6.06%	1.30N	172.48CN*CM	5.90CN/TEX	26.80Ne	3.63Sec

4.2. DISCUSSION

In this work the main focus was to obtain best quality banana fiber which can be used in many areas. The main parameters which affect the quality and mechanical properties of banana fiber was tried to studied and finally as within the scope of this study the better banana fiber production parameters are tried to be identified. As shown in above data the effect of various parameters were displayed. Based on that some parameters and their effect are discussed in short.

The mechanical properties such as elongation, work to break,tenacity,linear density and time to break are the most commonly used mechanical properties to explain the quality of textile fibers. The quality of textile fibers highly affected by above properties. In general by controlling the above three parameters it is possible to modify the mechanical properties of banana fiber. It is known that as the percentage of pure cellulose increase the desirable mechanical property of textile fiber increases. So if alkali treatment affect the concentration of pectin and lignin indirectly it means there will be an increase in concentration of cellulose and As a result the mechanical properties of treated fiber become improved and desirable.

It is already investigated that the mechanical property of banana fibers are highly affected by concentration, temperature and time. These three parameters can be optimized by taking the mechanical properties of banana fiber as a response variable. Accordingly it is seen that banana fiber mechanical property is not affected in short period of time even if the concentration of sodium hydroxide is high. This is because the reaction of pectin and lignin on the surface of banana fiber is with sodium hydroxide is a slow process.

The low concentration of NaOH and lower treatment time does not influence lignin and pectin removal and bring considerable change in banana fiber mechanical properties. The lignin and pectin removal is found poor for lower treatment time even with the higher concentration of NaOH. This is because the fibre requires some time to swell so that the further treatment agents can enter into the fibre. At lower time durations, whatever may be the concentration, it do to attack and decompose the lignin and pectin. In the same way, with the lower concentrations and higher treatment time, the alkali is not efficient to decompose the lignin and other impurities from the fibre.

This shows that low concentration of NaOH and lower treatment temperature do not influence the mechanical properties of banana fiber . The lignin removal is slightly increased even at lower treatment temperature but with higher concentration of NaOH. Temperature is necessary to make the fibre to swell and alkali concentration is a must to decompose the impurities from the fiber. With high concentrations, the increase in treatment temperature linearly increases the mechanical properties of banana fiber. At higher treatment time and lower temperature, the alkali action on fibre is not very fast. Because pectin the lignin decomposition is very low the effect on mechanical properties of the banana fiber. At longer treatment time and higher temperature the best results are obtained than at low temperature.

Higher concentration and at longer treatment time negatively influence the mechanical properties of banana fibers. So generally the optimum condition to obtain better quality fiber in the scope of this study moderate concentration relatively longer treatment time and high temperature produce best result. From the responses, optimum concentration, time and temperature for better mechanical properties of banana fiber without affecting

the cellulose fibrils of banana fibres are obtained. As observed from the results, the banana fiber produced at are 0.3M of NaOH concentration, 90°C of temperature and 60minute of treatment time shows excellent mechanical property as compared with others.

The linear densities of the untreated fibres are found to be lower about 9Ne and that of the optimally treated fibres showed higher values of linear density which is 26.08Ne. The increase in density is due to the treatment with silicone softeners, surface reaction and other treatment chemicals after alkali treatment.

5. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

- ❖ Banana fiber can be extracted mechanically with a percent yield roughly of about 22.2%.
- ❖ The mechanical property of banana can be modified through chemical treatment by controlling the parameters concentration, temperature and time of treatment.
- ❖ The mechanical property of banana fiber is highly affected by time of treatment then concentration and finally temperature in order.
- ❖ The effect of concentration and time of treatment should be optimized to produce high quality fiber which could be used in different sectors.
- ❖ Within the scope of this study a banana fiber treated with 0.3M of NaOH, at a temperature of 90⁰c for 60min with 5gram in 200ml material liquid ratio shows excellent result mechanical property.
- ❖ As the concentration of sodium hydroxide increases the mechanical property of the banana fiber first increases and then decreases as the concentration continues to increase.
- ❖ The mechanical properties of banana fiber do not affected at very short period of time even if the concentration of alkali is high.
- ❖ The linear density treated, bleached and silicone lubricated banana fiber is greater than the non treated one.
- ❖ The color of non treated banana fiber with alkali is better than the treated banana fiber before bleaching.
- ❖ The concentration and length of time for which banana fiber treated plays very important role in modifying the mechanical property and process ability performance improvement.
- ❖ Modified and improved banana fiber can be spun into yarns and then to fabrics blended with cotton or alone. More over the use of banana fiber in different textile industry , packaging industry and fiber glass industry in Ethiopia is undeniable.

Currently Ethiopia is suffering from lack of cellulosic raw material(cotton). About 40% of the cotton in Ethiopian textile industry is imported yet banana fiber can be a source of fiber in textile industry. So generally mechanically extracted banana and chemically treated banana fiber can be directly used in textile, packaging and glass fiber production industry.

5.2 RECOMMENDATION

In future work it is highly recommended to modify the spinnability ,making yarns, dyeing and fabrics of the obtained fiber. And I highly recommend that if further study is done over wider range of temperature , concentration and time including all variety of banana a best result could be obtained. Based on the information obtained in this research it is possible to obtain silk grade fiber with excellent spinnability with currently available textile machineries. More over there is a great chance of using this natural fiber as medo textile in textile industry for people allergy of synthetic fiber since such fabrics are free from any chemicals. For example sanitary pads for females and in diaper for babies made from this natural fiber can be produced effectively with further study. During production of banana fiber the produced waste such as pectin and lignin can be changed green fertilizers with further study. Any investor investing on production of banana fiber could get appreciable income for that it is able to produce low cost fiber to replace the wide use of synthetic fiber in different fiber using industrial sectors .

6. FUTURE SCOPE AND LIMITATION OF THE STUDY

6.1 future scopes

- ❖ In future the finishing process like making yarns, weaving, knitting and dyeing will be included.
- ❖ The research will be done over wide range of temperature, concentration and time of treatment.
- ❖ This research will include the wise use of the banana stem totally by avoiding any form of wastage like lignin and pectin produced during the process of fiber production
- ❖ It will include more variety of banana for production of fiber.
- ❖ It could be expanded to the production of highly durable and flexible and waterproof paper production which could be used in making currency.
- ❖ It could be seen from medical point of view as banana fiber textile is natural and non-allergic especially for internal body contacting wears like pants, modes and diapers.

6.2 LIMITATION OF THE STUDY

- ❖ The study is restricted to one variety of banana fiber which is widely distributed in different parts of the country.
- ❖ It is not possible to carry out all the possible treatment type due to limited resource of time and money.
- ❖ As the use of banana fiber in textile industry by changing into yarns and fabrics is a new concept and technology there is a lack of experience and literature.
- ❖ There is hardly any reported work on the process ability performance improvement with the effect of temperature, concentration and time of treatment
- ❖ The study is restricted to a certain range and levels of only three factors. There may be other factors which affect the mechanical properties of banana fiber which are not investigated in this study.

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7. APPENDIXES