BUSITEMA UNIVERSITY
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FACULTY OF ENGINEERING

Department af Textile and Ginning Engineering

DEVELOPMENT OF TEXTILE YARN FROM A BLEND OF *Musa Sapientum* BANANA – COTTON FIBRES

BY

AKANYIJUKA MARK

BU/UG/2010/265

akanyijukamark273@gmail.com

0775443344/0703040996

SUPERVISORS

Eng Samson Rwawiire

Eng Martin Ssembatya

Madam Catherine Namuga

The project report submitted to the department of ginning and textile engineering as a requirement to the partial fulfillment to the award of a Bachelor of Science degree in Textile engineering of Busitema University

May 2014

ACKNOWLEDGEMENT

First, I would like to thank the almighty God who has enabled me come this far. I thank my supervisors; Mr. Samson Rwawiire, Mr. Martin Ssembatya, and Madam Namuga Catherine whose tremendous contributions have enabled me do this project and prepare this report - I treasure them academically!

I am particularly grateful and thank my beloved parents Mr. and Mrs. Rubaramira for their moral, material and financial support during the entire period when I was doing this project. Their presence and contribution saw me move from one stage to the other to completion.

I thank all course mates and friends who encouraged me during the period of conceptualizing the idea and proposal writing and finally final presentation and report writing, they matter to me.

Finally, I thank the Almighty God for keeping me safe and sound to this time

DECLARATION

I AKANYIJUKA MARK, hereby declare that each piece of information presented in this report is my own work and that to the best of my knowledge has never been submitted by any other person to any institution of higher learning for the same academic award.

Signature

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Date. 27th May, 2014

APPROVAL

I do hereby present this project proposal report for approval as supervised by the following supervisors during writing.

1. Mr. Samson Rwawiire
   Main supervisor
   Signature.....................................
   Date...

2. Mr. Martin Ssembatya
   Co-supervisor
   Signature.....................................
   Date...

3. Madam Namuga Catherine
   Co-supervisor
   Signature.....................................
   Date...

DEDICATION

To all scientists who desire to see new technologies in place and my beloved parents Mr. and Mrs. Rubaramira.

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ABSTRACT

The textile industry in Uganda is one of the most important sectors necessary to develop the economy if the Uganda National Textile Policy vision is to be implemented whose vision is; to create a strong and vibrant textile and clothing industry with sustainable capacity utilization and enhanced investment through the textile value chain. The vision is directed to the achievement of Uganda's ***Vision 2040***. Uganda's textile mills mainly use synthetic fibers most of which are imported and cotton. There is still an underutilized potential in natural fibers and in particular Banana Fibers.

The interest in natural fibers has increased significantly in the last few years. The abundance in nature combined with the ease of its processing is an attractive feature which makes it an important substitute for synthetic fibers which are potentially toxic. These lingo-cellulosic fibers possess many characteristics which make their use advantageous; low cost, low density, biological degradability, renewability, good mechanical properties and non-toxic. Examples of natural fibers are; banana, cotton, sisal, jute, bamboo, silk, flax etc

Globally and in Uganda, production of bio-degradable textile materials is being encouraged. Most textile products on market today are made of synthetic fibers. The production of these materials is not eco-friendly and requires strong and toxic chemicals and high temperatures leading to generation of hazardous wastes. The disposal of these wastes is a major environmental and economic challenge thus need for a bio-degradable fabric from banana fiber cotton blend that is comfortable to wear and cost effective. The main objective of this project was; **to develop a textile yarn from a blend of *Musa Sapientum* Banana-Cotton fibres**. Blending was first done by hand and later the mixed fibres were taken to the Lab-scale Card to achieve proper blending and parallelization.

The project established that blend ratios of 80:20, 70:30 and 65:35 and that they were possible, a perfect blend being obtained using the lab scale card machine or any other machine that can be adapted to that purpose. Also it was found that the filament sisal-like banana fibres can be softened by boiling them in lye or wood ash to the required level of softness.

Products made out of Banana Fibre Cotton blend are bio-degradable since they are all cellulosic in nature. These products also have good aesthetic properties which makes them comfortable to wear. The use of waste BF will also lead to increase in banana farmer's income and if well exploited nationally can increase the country's Gross Domestic Product (GDP) in the long run.

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ABBREVIATIONS

MT: Metric Tones

Ha: Hectare

MAAIF: Ministry of Agriculture, Animal Industry and Fisheries

UBOS: Uganda Bureau of Statistics

FAO: Food and Agriculture Organization

GDP: Gross Domestic Product

BF: Banana Fibres

CHAPTER 1: INTRODUCTION

1.1Background

The textile industry in Uganda is one of the most important sectors necessary to develop the economy if the Uganda Vision 2040 is to be achieved. Uganda's textile mills mainly use synthetic fibers most of which are imported and cotton. There is still an underutilized potential in natural fibers and in particular Banana Fibers.

In Uganda, bananas are grown in all regions as shown in the table below;

Table 1 Banana Production by Region in Uganda; 2008

Region	**Area Planted (Ha)**	**Production (MT)**
Central	326,082	1,039,837
Eastern	69,504	342,234
Northern	9,195	31,626
Western	511,096	2,883,648

SOURCE: UBOS and MAAIF (Uganda Census of Agriculture)

The interest in natural fibers has increased significantly in the last few years. The abundance in nature combined with the ease of its processing is an attractive feature which makes it an important substitute for synthetic fibers which are potentially toxic. These lingo-cellulosic fibers possess many characteristics which make their use advantageous; low cost, low density, biological degradability, renewability, good mechanical properties and non-toxic. Examples of natural fibers are; banana, cotton, sisal, jute, bamboo, silk, flax etc....

Banana plant not only gives the delicious fruit but it also provides textile fiber, the banana fiber. It grows easily as it sets out young shoots and is most commonly found in hot tropical climates. All varieties of banana plants have fibers in abundance. These fibers are obtained after the fruit is harvested and fall in the group of bast fibers. This plant has long been a good source of high quality textiles in many parts of the world, especially in Japan and Nepal.

Now a day, Natural Fibers (NF) is preferable for their appropriate stiffness, mechanical properties and high disposability. Banana Fiber (BF) is a lingo-cellulosic fiber obtained from the pseudo stem of the banana plant (Musa Sapientum), bast and has relatively good mechanical properties.

BF is a multicellular structure whose lumens are large in relation to the wall thickness and its tips pointed and flat individual fibre diameter ranges from 14 to 50 microns and the length from 0.25 to 1.3cm, showing the large oval round lumen. (*Davies,1995*).

BF is a natural fibre with high strength which can be blended easily with cotton or other synthetic fibres to produce blended fabric (*Rubaihayo 1991*).

Increasing demand of eco-friendly fibre worldwide is high. The real cost involved in production of BF comes from waste collection and fibre extraction which is negligible in comparison with the other natural fibres such as cotton, jute and hemp (*FAO, 2005*)

Banana fibers in Uganda are mainly used for tying, and making of simple handicrafts like hand bags, ropes, shopping bags, ladies sanitary pads and hand-made paper.

Fig.1 Photograph showing a Banana Plantation in Kawanda (28/10/2013)

1.2 Problem statement

Globally and in Uganda, production of bio-degradable textile materials is being encouraged. Most textile products on market today are made of synthetic fibers. The production of these materials is not eco-friendly and requires strong and toxic chemicals and high temperatures leading to generation of hazardous wastes. The disposal of these wastes is a major environmental and economic challenge thus need for a bio-degradable fabric from banana fiber that is comfortable to wear and cost effective.

1.3 Justification

Banana growing in Uganda dates back several years ago. This is a clear indicator that it is in abundance since at least every household in western, central and part of eastern Uganda has a banana plantation. A staple crop in much of Uganda, banana is grown by between 50 and 70 per cent of the farmers in the country. It is consumed locally, making the country the world's highest per capita banana consumer at 250 kilograms per person in a year and among the top producer of bananas in the world. The banana crop occupies about 67 per cent of all cropped land in Uganda. This makes raw materials readily available. *http://textileacross.blogspot.com/2009/01/eco-friendly-banana-fiber.html*

Products made out of BF are bio-degradable since they are cellulosic in nature. These products also have good aesthetic properties which makes them confortable to wear. The use of waste BF will also lead to increase in banana farmer's income and if well exploited nationally can increase the country's Gross Domestic Product (GDP) in the long run.

1.4 Objectives of the study

1.4.1 Main objective

To develop a textile yarn from a blend of *Musa Sapientum* Banana-Cotton fibres.

1.4.2 Specific objectives

- To optimize extraction of banana fibers for the textile fabric through boiling in wood ash.
- To improve the yarn quality by blending the banana fibres with cotton fibres.
- To investigate the produced yarn properties in comparison to cotton yarn.

1.5 Scope of the study

The study will be limited to the banana pseudostem from where the banana fibers will be extracted. It also exclusively studies the fibers from the Ugandan local varieties of edible type (Musa Sapientum). Selected physical and mechanical properties of banana fibers will be tested and compared with those of locally available textile fibers.

CHAPTER 2: LITERATURE REVIEW

2.0 General Introduction

Trees and plants provide mythological and factual stories, and are a vital member of our planet. Banana plant is endowed with virtuous fibres which can be used to make good apparels. Though, the plant is more popular for its fruit, it has been a source of high quality fibre which is used to manufacture textiles. Banana fibre is a kind of fibre extracted mainly from the barks of banana plant. Similar in appearance to the bamboo fibre, it belongs to bast fibre, and its chemical composition is mainly of cellulose, lignin, and hemi cellulose.

2.1 BIODIVERSITY OF BANANAS ON FARMS IN UGANDA

Uganda is among the world's leading countries in terms of banana production and consumption. Bananas occupy the largest cultivated area among staple food crops in Uganda and are primarily grown in small subsistence farms (plots of less than 0.5 ha).

In addition to being a major food staple, bananas are important source of income, with excess production sold in local markets. Average per capital annual consumption of bananas is highest in the world, estimated at close to 1kg per person per day. Bananas are consumed as fruit, prepared for cooking, roasting or drying, and fermented for the production of banana juice and alcoholic beverages (beer, wine and gin).

Most of the banana varieties grown in Uganda are endemic (indigenous) to the East African Highlands in a region recognized as a secondary centre of banana diversity. The East African Highland banana is a unique genomic group, selected over the centuries by farmers. As many as 84 distinct varieties of endemic East African Highland bananas, classified into five clone sets, are grown by farmers in the region (*Karamura, 1998*)

Table 2. Variety and use group diversity in number of Banana Varieties at the household and village levels

	Number of banana varieties			
Unit of analysis/elevation	Minimum	Maximum	Mode	Mean
Household, varieties				
Low elevation	1	15	4	6.72
High elevation	2	27	6	9.07
Household, use groups				
Low elevation	1	5	4	2.65
High elevation	1	5	3	3.36
Household, cooking varieties				
Low elevation	0	14	4	4.83
High elevation	1	18	3	6.39
Village, varieties				
Low elevation	13	32	20	22.41
High elevation	17	36	32	25.54

Note: Household sample sizes are 417 in low elevation areas and [illegible] in high elevation areas; the total number of communities is 27.

In addition, several unimproved, exotic banana varieties from Southeast Asia and a few recently developed hybrids are also locally grown. Differences between endemic and non-endemic varieties are associated with differences in observable characteristics, genome, and common use, but not with improvement status.

The biological diversity of bananas in Uganda is understood at the taxonomic levels of genomic group, use group, and variety. This diversity is impressive at all geographical scales of analysis—the household farm, the village, and the region. Although banana specialists in East Africa have long made this observation, the sample survey undertaken as part of the research described here establishes this fact statistically for the major banana-growing regions of the country. Survey data confirm the high level of banana diversity both in the country as a whole and on individual farms (Table 1). A total of 95 banana varieties are currently grown among the households sampled in Uganda, with the majority (86 percent) consisting of endemic types. Banana varieties, which are locally named and differentiated by characteristics that are observable to farmers, were classified in this research into synonym groups according to established banana taxonomy, resulting in five groups or types defined by use (cooking, beer-making, sweet, roasting, and multi-use).

Differences in consumption preferences, genetic composition, and the manner in which that genetic makeup interacts with the environment mean that no single variety equally supplies the attributes demanded by farm families (Bellon 1996). The typical household in Uganda grows, on average, as many as 7 banana varieties simultaneously in the banana grove, with a maximum of 27. Farmers consider different banana varieties to have distinct advantages and disadvantages in regard to both consumption needs and production requirements. Another reason farmers maintain so many varieties simultaneously is that they serve as living stocks, reducing the reliance of farmers on cumbersome, longer distance exchanges of planting material to obtain the desired range of varieties and traits. Many households grow three or more use groups of varieties. Endemic cooking bananas are the most widely grown use group in the sample, with 97 percent of households growing at least one cooking variety. The diversity within this group is also striking. Most farm house- holds grow three or more distinct cooking-banana varieties, with an average of five. The number of distinct varieties per village ranges from 13 to 38, with an average of 23. Major varieties appear to be fairly uniformly distributed across households. The varieties most frequently grown by farmers are generally the same as those that are most widely planted. Among them, endemic cooking bananas predominate, highlighting the greater importance farmers place on local banana types compared with introduced varieties.

Nevertheless, even the most widely grown banana varieties account for less than 10 percent of all banana stands in the entire sample. This indicates the tremendous clonal diversity maintained by farmers across the major banana-producing regions of Uganda. The criteria used to select among varieties depends on the region and whether the farmer is oriented to ward subsistence or commercial production. Insight into the specific traits that motivate farmer selection of a given variety is limited and primarily derived from on-station research trials rather than on-farm surveys.

The relationship between morphological or trait diversity and the utility of these traits to farmers is also poorly understood (Gold et al. 1998; Karamura, Hartman, and Kaplan 1999). To address these limitations, surveydata were used to gain greater insight into the role of farmers' perceptions of the importance of specific banana attributes in their decisions regarding which varieties to grow, in particular the number and mixture of varieties.

A full taxonomy of banana clones was used to construct measures of diversity(as defined by the number and evenness) at the variety and use group levels on farms of smallholder, semi-subsistence banana-producing households in Uganda. The relative importance assigned to different attributes by farmers influences the trade-offs they make when choosing the type and number of varieties to grow, which is believed to affect banana diversity on farms. Key attributes sought by farmers include resistance to black Sigatoka, weevils, and Fusarium Wilt, as well as cooking and beer-brewing quality. Diversity indexes were constructed and used in an economic model to explore the associations between the observed levels of diversity across varieties and use groups and the importance that households place on specific variety attributes.

The findings underscore the importance of variety attributes in explaining the decisions of banana growers in Uganda.

The higher the number of attributes rated as very important, the greater the number and evenness of varieties grown. In addition, the more important cooking quality is to the household, and the less important beer-brewing quality, the greater the diversity of use groups.

This suggests that a focus on beer brewing for cash, rather than food, reduces the range of groups. Specialization by use group has implications for resistance evolution in pests and diseases and adoption of particular varieties because use groups vary in resistance.

Furthermore, the differential vulnerability to pests and diseases among varieties probably explains the effects of these biotic stresses on the diversity of banana varieties and use groups maintained by farmers. Vulnerability was measured in this study both in terms of farmers' perceptions of the frequency of occurrence of pests and diseases in their plantation and the relative importance of the biotic stress. Although trade-offs across use groups are found when cooking and beer-brewing quality are considered, production traits are generally more important than consumption attributes in explaining variety diversity. Maintaining diversity could be a deliberate strategy for managing abiotic and biotic pressures in this relatively labor-intensive production system with low levels of chemical inputs.

2.1.1 Results of the survey

The survey results indicate that wealthier farmers holding more value in livestock assets are more likely to grow larger numbers of distinct varieties and use groups, which are more evenly distributed. An association was also found between the experience of the primary household decision maker on banana production and the variety and diversification of use groups. By contrast, the decision maker's gender is not associated with the diversity. The availability of large stocks of diverse banana planting material in the community is positively associated with greater number of varieties on individual farms.

When the range of variety attributes demanded by subsistence farmers is limited, dissemination of planting material (either improved or landrace) can have a positive effect on crop biological diversity. The results also suggest positive associations between the age of the plantation and both variety and use group diversity.

The older the plantation, the longer the time span families have had to accumulate diverse banana types within and over generations of managers. Market sales induce farmers to grow a wider and more even range of banana varieties and use groups. Buying bananas is associated with less variety diversity and more use group diversity because farmers depend less on their own stocks for food. Bananas are vegetatively propagated, and a unique system of reproduction and dissemination of planting material exists among farmers. Banana production in Uganda is primarily driven by subsistence needs rather than commercial goals. On the one hand, the overwhelming importance of attributes and the extensive biological diversity on farms in Uganda suggests that newly improved banana varieties will not displace local varieties in the near future. Still, judicious introduction of newly improved banana varieties will be important if , in addition to relieving productivity and market constraints to banana production, protecting biological diversity in the East African highland banana is of policy concern. Genetic transformation is one way to maintain the diversity of types that farmers recognize and find useful, since this technique maintains the original traits of a variety while adding additional desired trait(s) (Sági, Remy, and Swennen 1997). On-farm diversity has implications for adoption of transgenic bananas. Even if many farmers adopt a new variety, the variety may constitute only a small share of the total banana population because no single variety dominates with respect to all uses or attributes. On the other hand, uneven, spatially discontinuous adoption could be beneficial in terms of managing pest and disease evolution, extending the usefulness of the inserted trait and the economic advantage farmers earn from adopting transgenic varieties.

2.2 Banana Fibres

Banana fibres are thread like and thick wall cells in plants. They are always long and can be easily extracted from the plants. The fibres usually can be grouped according to the origins of the plant. Banana fiber, a ligno-cellulosic fiber, obtained from the pseudo-stem of banana plant (Musa sepientum), is a bast fiber with relatively good mechanical properties.

Plant fibers are schlerenchymatous cells with heavily lignified cell walls having a narrow lumen in cross section. Fiber cells are dead at maturity and serve as a support tissue. Natural fibers possess several advantages over synthetic fibers such as low density, appropriate stiffness and mechanical properties and also high disposability and renewability. Also, they are recyclable and biodegradable. Banana fibers can be used for various purposes such as in textile, paper or handicrafts industry (*Alhayat, 2012*)

2.3 Methods of Extraction

2.3.1 Japanese Method

In the Japanese system, leaves and shoots are cut from the plant periodically to ensure softness. Harvested shoots are first boiled in lye to prepare fibers for yarn-making. These banana shoots produce fibers of varying degrees of softness, yielding yarns and textiles with differing qualities for specific uses. For example, the outermost fibers of the shoots are the coarsest, and are suitable for tablecloths, while the softest innermost fibres are desirable for kimono and kamishimo. This traditional Japanese cloth-making process requires many steps; all performed by hand (***www.thefiberofmybeing.net***)

2.3.2 Nepalese Method

In Nepal, the trunk of the banana plant is harvested instead of the shoots. Small pieces of these trunks are put through a softening process for mechanical extraction of the fibers, and then bleaching, and drying. The fiber obtained thus has appearance similar to silk which has become popular as banana silk fiber yarn. This fiber is refined, processed and skeined mostly by the Nepalese women. Only the aged bark or the decaying outer layers of the banana plant are harvested and soaked in water to quicken the natural process. When all the chlorophyll is dissolved, only the cellulose fibers remain. They are extruded into pulp so that they may become suitable for spinning into yarn. The yarn is then hand- dyed. They have high textural quality similar to silk and as such employed in making high end rugs. These traditional rugs are woven by hand-knotted methods again by the women of Nepal. ***www.thefiberofmybeing.net***

2.4. Banana Fibre – Structure and Usage

Banana plants coarse outer layer is commonly used for woven tablecloths, cushions, seating, and curtains, while the inner, silky layer is ideal for fine saris, kimonos, and eco-couture designs like the above "Doo-Ri" dress. (*http://www.kougei.or.jp*)

Banana fibers can be extracted by employing chemical, mechanical or biological methods. Chemical method causes environmental pollution, while mechanical method fails to remove the gummy material from the fiber bundle surface. Biological procedures yield more fiber bundles than the other two procedures without any harm to the environment. The extraction of banana fibers using biological natural retting has already been reported. After extracting the fibers, degumming is essential prior to the utilization of fibers. The removal of heavily coated, non-cellulosic gummy material from the cellulosic part of plant fibers is called degumming.

Banana fiber is a multiple celled structure. The lumens are large in relation to the wall thickness. Cross markings are rare and fiber tips pointed and flat, ribbon like individual fiber diameter range from 14 to 50 microns and the length from 0.25 cm to 1.3 cm, showing the large oval to round lumen. Banana fiber is a natural fiber with high strength, which can be blended easily with cotton fiber or other synthetic fibers to produce blended fabric & textiles. Banana Fiber also finds use in high quality security/ currency paper, packing cloth for agriculture produce, ships towing ropes, wet drilling cables etc.

The ''pseudo-stem'' is a clustered, cylindrical aggregation of leaf stalk bases. Banana fiber at present is a waste product of banana cultivation and either not properly utilized or partially done so. The extraction of fiber from the pseudostem is not a common practice and much of the stem is not used for production of fibers. The buyers for banana fibers are erratic and there is no systematic way to extract the fibres regularly. Useful applications of such fibres would regularize the demand which would be reflected in a fall of the prices.

Bast fibers, like banana, are complex in structure. They are generally lingo-cellulosic, consisting of helically wound cellulose micro fibrils in amorphous matrix of lignin and hemicellulose. The cellulose content serves as a deciding factor for mechanical properties along with microfibril angle. A high cellulose content and low micro fibril angle impart desirable mechanical properties for bast fibers. Lignins are composed of nine carbon units derived from substituted cinnamyl alcohol; that is, coumaryl, coniferyl, and syringyl alcohols. Lignins are associated with the hemicelluloses and play an important role in the natural decay resistance of the lingo-cellulosic material (*textileacross.blogspot.com*)

2.5 Characteristics of Banana Fibres

Banana fiber is a natural bast fiber. It has its own physical and chemical characteristics and many other properties that make it a fine quality fiber.

- Appearance of banana fiber is similar to that of bamboo fiber and ramie fiber, but its fineness and spinnability is better than the two.
- The chemical composition of banana fiber is cellulose, hemicellulose, and lignin.
- It is highly strong fiber.
- It has smaller elongation.
- It has somewhat shiny appearance depending upon the extraction & spinning process.
- It is light weight.
- It has strong moisture absorption quality. It absorbs as well as releases moisture very fast.
- It is bio- degradable and has no negative effect on environment and thus can be categorized as eco-friendly fiber.
- Its average fineness is 2400Nm.
- It can be spun through almost all the methods of spinning including ring spinning, open- end spinning, bast fiber spinning, and semi-worsted spinning among others. (*www.thefiberofmybeing.net*)

Table 3.Chemical composition of banana fibres

Composition	Percentage (%)
Cellulose	62
Lignin	29
Hemicellulose	3
Rectin	2
Miscellenious	4

SOURCE:*www.ukessays.com*

CHAPTER 3.METHODOLOGY

3.0 Introduction

The extraction of banana fibers was done manually by hand using a panga. The obtained banana filament fibres were then boiled in wood ash in order to soften them. The cotton-like banana fibres from the *Musa Sapientum* pseudo stem were later on mixed or blended with 100% cotton and used for yarn making in the laboratory using the lab scale carding machine and the lab acale ring spinning machine.

The produced yarn was then tested for its physical properties at the physical testing laboratory in Nytil – Jinja.

3.1 Procedure of Extraction of Soft Short Staple Banana Fibers

- These fibres were extracted by hand using a panga or knife.
- The extraction involved stripping off the outer sheath of the banana pseudostem
- The inner cone of the pseudostem was left.
- The stem was cut or chipped with a panga into small pieces.
- At each cutting, the soft fibres were exposed and pulled by the hand fingers and placed on a clean place (banana) leaf where they were collected from in preparation for drying.
- The wet extracted cotton-like banana fibres were then allowed to dry in free circulating air to remove the high moisture content.
- The fibres were kept in a clean environment awaiting further processing into yarn.

Fig 2.Procedures followed in extraction of fibres from the pseudo stem of *Musa Sapientum*

Fig 3.Extraction of the soft cotton-like banana fibres.

3.3 Blending of Banana Fibre and Cotton

Blending refer to the process of mixing different kinds of textile fibres in order to compliment the performance properties of one fibre with those of the fibre it is blended with. Blending of banana fibre and cotton fibres was done. It was done using selected blend ratios on the basis of weight.

In all the bend ratios below, cotton is in higher proportions than banana fibre because banana fibre is weaker than cotton fibres. Therefore, there was need for improving strength of the blend by using more cotton

3.3.1 How blending was done

Banana fibres were first weighed on the lab scale weighing scale of model PGW 753e whose maximum load capacity is 750g.

After weighing, the fibres were given a preliminary blend by hand before they were fed to the Lab Scale Carding machine from the **MESDANLAB code 337A**.

During blending, the following blend ratios were used;

80:20, 70:30 and 65:35 all Cotton to Banana Fibre ratios. The ratios were obtained by weight.

After placing them on the feed plate of the lab scale carding machine, the fibres were first sprayed with the Duron Spray used in textile processing. This is for faint spraying on fibres, yarns, bobbins or man-made fibre fabrics. It eliminates static charges, as for example on converters, high speed draw frames, warping frames, looms etc. This spray also eliminates condensation on cold machinery.

3.4 Process of sliver formation and ways of ensuring that a uniform sliver is obtained after the lab scale carding machine

After the carding stage was done sliver was formed. In order to produce a good quality web, it was ensured that the fibers fed were well opened. Opening helps the fibres to easily align themselves along the card rollers as the web is being formed.

After web formation, a sliver was made manually by rolling/coiling the web and inserting a small level of twist in order to make the fibres adhere to one another. Coiling of the web was done on a smooth flat and clean table to ensure that there is no contamination.

Fig 8. The process of sliver formation

The sliver formed at this stage was sprayed with Duron Antistatic Spray used in textile processing in order to eliminate static charges that may cause fires during processing.

3.5 Spinning of the sliver into yarn

Spinning of the produced sliver was done on the lab scale ring spinning machine from the **MESDANLAB Code 3108A** in the textile laboratory, Busitema University.

3.6 Procedure of making the lye out of wood ash

- A lot of holes were drilled in the bottom of a small wooden barrel, which was waterproof before drilling the holes.
- Stood the barrel on blocks leaving space beneath the barrel for a container.
- Used a waterproof plastic container because lye can burn through some metals.
- Put a layer of gravel in the bottom of the barrel over the holes.
- Filled the rest of the barrel with hardwood ash that was burnt on a local charcoal stove, leaving a couple of inches at the top clear.
- Then poured rainwater into the barrel. After a long time the water in the barrel started dripping into the container.
- Left it until it stopped then replaced the container with another so as to collect odd drips.
- A strong a steel pan was used, boiled the liquid until it became so concentrated that a fresh egg (still in its shell) floated on top.
- The egg was destroyed.
- Took all precautions not the let the liquid touch the skin or clothing.

3.7 Softening process of the filament fibres

The extracted fibres were boiled in lye made out of wood ash in order to soften them. The boiling times were varied in order to obtain varying degrees of softness and compare the results.

3.8 Denier and yarn count

A predetermined length of fibres was cut from each yarn sample and counted to determine their number of ends in the test sample. Each sample was labeled for easy identification and weighed to determine the weight.

3.9 Tenacity and elongation Test

This was measured on the Uster Tensor rapid 3 (UTR3). It uses the constant rate of elongation principle.

The sample was automatically fixed in two clamps, with a predetermined pretension and a fixed test length. The top clamp remained stationary while the other moved away from the fixed clamp at a constant but adjustable speed. Strength and elongation values were taken from the scale and noted in the tables below.

CHAPTER 4 RESULTS INTERPRETATION AND DISCUSSIONS

This chapter shows the results obtained from implementing the project at all stages.

After extraction and blending of cotton and banana fibres, the following blend ratios were practically reached at as illustrated below.

4.1 The different blend ratios obtained.

Fig 5. 65:35(Cotton: Banana fibre)

Fig 6. 80:20(Cotton: Banana fibre)

Fig 7. 70:30(Cotton: Banana fibre)

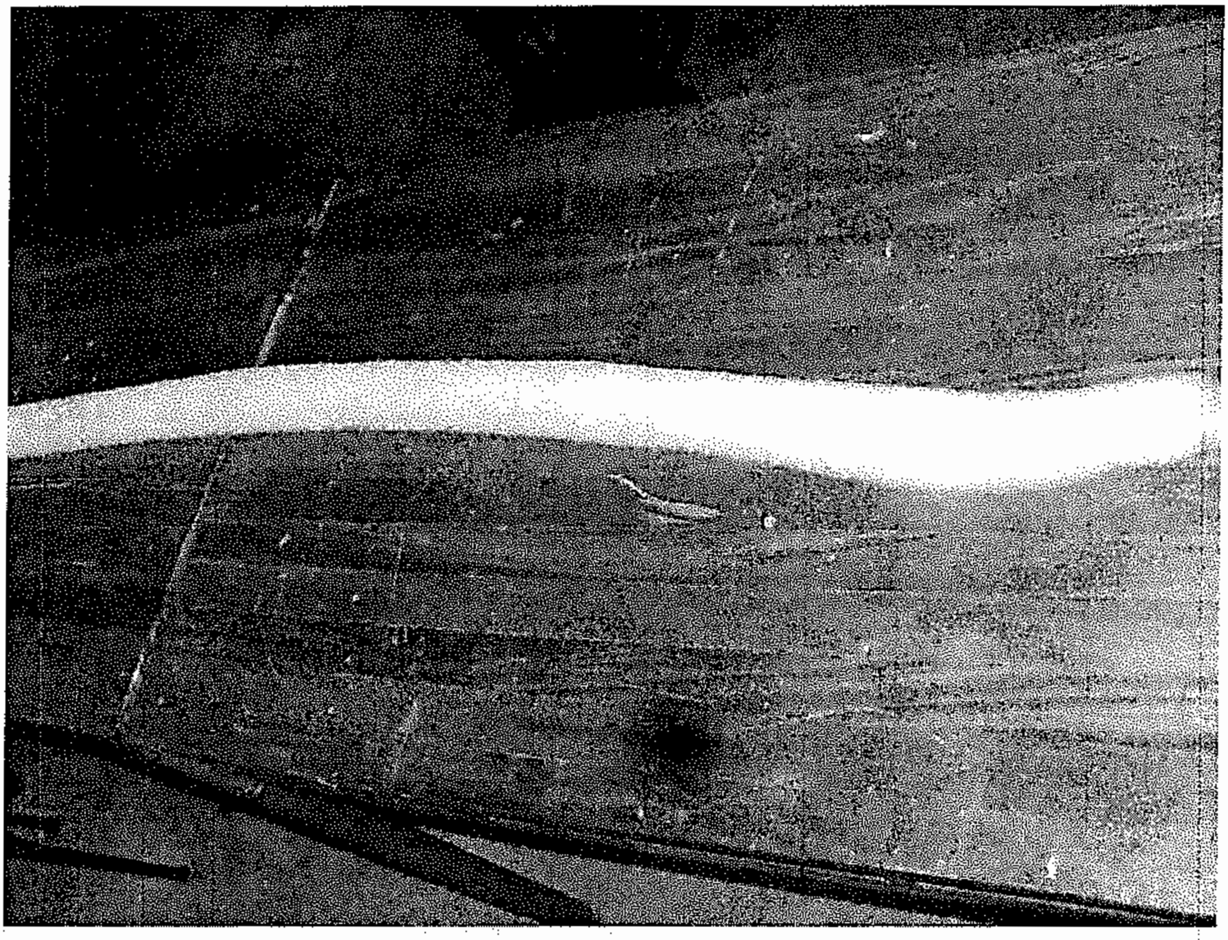


Fig 9. Obtained sliver on the table in the lab before it was transferred to the ring spinning machine.

4.2 Results from the lab scale spinning machine

During spinning, the following settings were used to process the sliver for yarn and the following observations were made during the process.

Table 4.The Lab Scale Ring Spinning Machine Settings used during spinning for the 80:20, cotton to banana fibre blend ratio

S/N	Setting	Value Used
1	Preliminary Draft	1.2
2	Twist	694
3	r.p.m'	5318
4	Total Draft	12.4
5	m/m'	7.7

- At this speed, no yarn break was recorded
- The balloon shape was normal

Table 5.The Lab Scale Ring Spinning Machine Settings used during spinning for the 70:30 and 65:35, cotton to banana fibre blend ratios

S/N	Setting	Value Used
1	Preliminary Draft	1.2
2	Twist	691
3	r.p.m'	5209
4	Total Draft	12.1
5	m/m'	7.5

- The yarn broke twice during its formation
- The broken yarn was joined and spinning continued
- The twist in the produced yarn was less leading to lower strength than the 80:20 blend where the twist level was higher

Fig 10. Samples of yarn obtained from the different blend ratios on their cones.

4.3 Results obtained from the tenacity and elongation tests

Table 6. 70/30 Blend (Y1)

Test Sample	Elongation (%)	Strength (g/den)
1	4.6	400
2	6.0	380
Average	5.3	390

Table 7. 65/35 blend (Y2)

Test Sample	Elongation (%)	Strength (g/den)
1	6.6	380
2	6.8	400
Average	6.7	390

Table 8. 80/20 Blend (Y3)

Test Sample	Elongation (%)	Strength (g/den)
1	10	500
2	10	560
Average	10	530

Table 9. 100% Cotton (Y4)

Test Sample	Elongation (%)	Strength (g/den)
1	11.2	580
2	11.8	570
Average	11.5	575

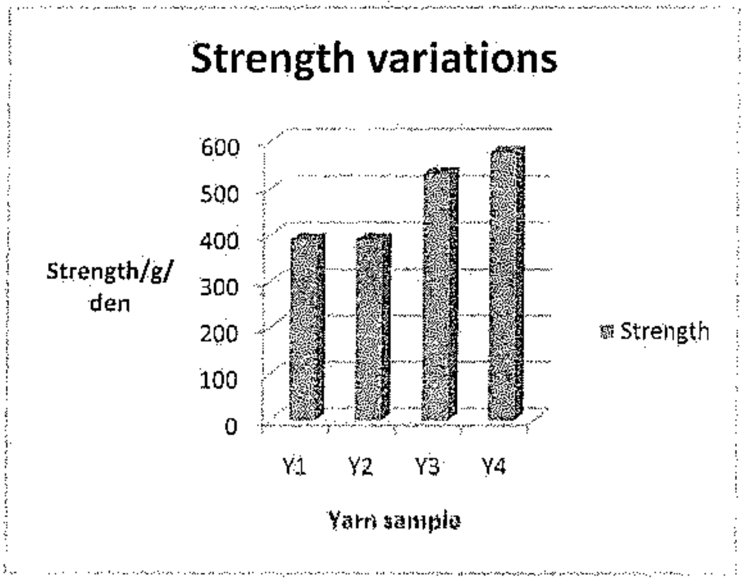
Table 10. Average Elongation compiled

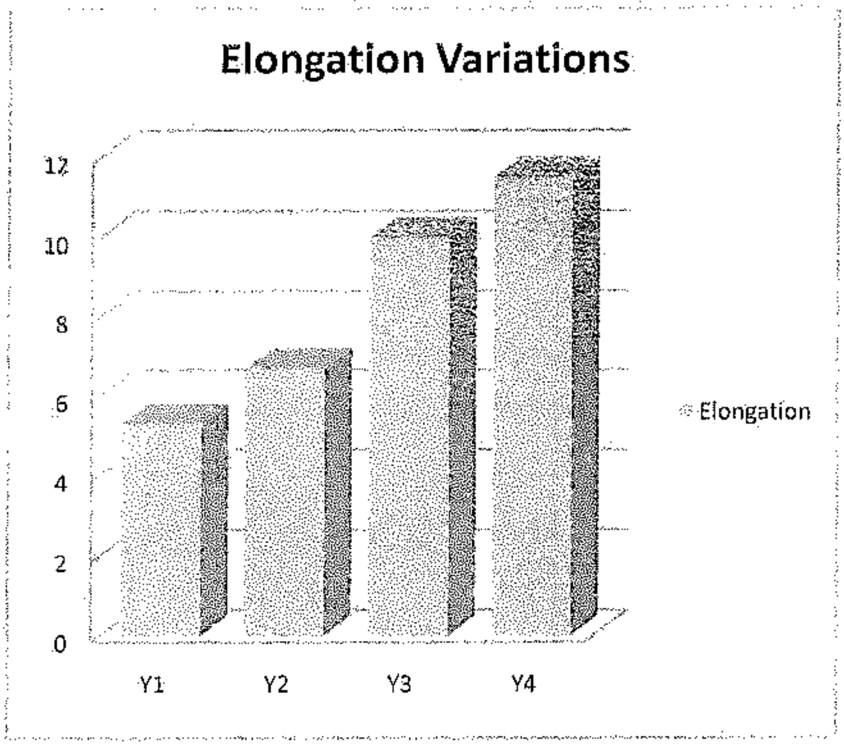
S/N	Yarn Sample	Averege Elongation(g/den)
1	Y1	5.3
2	Y2	6.7
3	Y3	10
4	Y4	11.5

4.4 The interpretation of the graph showing strength variations below is given here;

The average values of strength from the results were compiled and used here.

- The strength of the yarn samples Y3 and Y4 was recorded as being higher then that of Y1 and Y2.
- The above variations in strength could be due to the levels of twist that were inserted during making of yarns Y3 and Y4.





4.4.1 Interpretation

The average values of elongation were also used here.

The elongation of samples goes on increasing, that of Y4 being higher than for all the rest because it is also stronger than them.

4.5 Denier and yarn count results

Table 11.Sample test weights

Sample	Length of test sample(cm)	No. of yarns in the Test sample	Weight(g)
Y1	14	10	0.081
Y2	14	10	0.084
Y3	14	10	0.074
Y4	14	10	0.056

$$Ne = \frac{0.005905 \times length(cm) \times Number\ of\ ends}{Weight(grams)}$$

$$Denier = \frac{Average\ weight\ of\ the\ filament}{Average\ length} \times 9000$$

Table 12.Count and Denier results of the samples

Sample	Count(cm per gram)	Denier(g/cm)
Y1	$\frac{0.005905 \times 14 \times 10}{0.081}$ =10.206	$\frac{0.081}{14} \times 9000$ =52.07
Y2	$\frac{0.005905 \times 14 \times 10}{0.084}$ =9.8417	$\frac{0.084 \times 9000}{14}$ =54.00
Y3	$\frac{0.005905 \times 14 \times 10}{0.074}$ =11.172	$\frac{0.074 \times 9000}{14}$ =47.57
Y4	$\frac{0.005905 \times 14 \times 10}{0.056}$ =14.763	$\frac{0.056 \times 9000}{14}$ 36

Table 13.The values of denier and count obtained above are tabulated in the table below,

Yarn Sample	Count (cm/g)	Denier (g/cm)
Y1	10.206	52.07
Y2	9.842	54.00
Y3	11.172	47.57
Y4	14.763	36.00

4.6 CHALLENGES

- The extraction of the soft banana fibres was manual and a hectic process, takes a lot of time and requires a lot of patience.
- After blending cotton and banana fibres, it was not possible to test for the fibre blend properties on the USTER HVI 1000 Machine at the CDO laboratory as it was proposed. Only the properties of cotton that was used in blending were tested. The blend properties still need to be established.
- There was a challenge of making a roving from the web made on the lab scale card. This was made by hand and led to production of a non uniform roving which later translated to weak yarn.
- Challenge of testing for all the yarn properties since the physical testing lab at Nytil could not test for most of the proposed properties.

4.7 RECOMMENDATIONS

- The use of banana fibres for textile applications will greatly contribute to making the textile industry in Uganda more vibrant than it is today.
- The fibres blended together in the above ratios can be used for producing yarn for fabric production if its strength is improved and for other technical textile applications.
- More research needs to be done to establish the properties that have not been tested like the thermal comfort properties (Thermo gravimetric analysis) and other physical and mechanical properties.

4.8 CONCLUSIONS

- The project established that blend ratios of 80:20, 70:30 and 65:35 and that they were possible, a perfect blend being obtained using the lab scale card machine or any other machine that can be adapted to that purpose.
- The goal of the project was partly met because some other properties were not got due to lack of testing equipments.
- In the nutshell, banana fibres can be used for textile applications like in yarn making for both weaving and knitting leading to our nation having a more sustainable textile industry for clothing its ever increasing population.

4.9 APPENDICES

Fig 11.Preliminary blend on the card.

Fig 12. Web emerging from the carding machine

Fig 13. Blended fibers ready for carding

Fig 13. Results from the CDO Lab for Cotton Properties

Cotton Development Organisation

System Testing - Individual Tests

USTER® *HVI 1000*

Lot ID	BUSITEMA UNIVERSITY-DEMO GINNERY	**Catalog**	A
Operator		HVI SW Version	3.2.2.15
Print Date	3/10/2014	Serial Number	1209135
Print Time	4:09:15PM	Test Mode	1
Short/Weak Reference	Upland 34087	Long/Strong Reference	Upland 34327

Bale ID	SCI	Grade	Mst [%]	Mic	Mat	UHML [mm]	UI [%]	SF [%]	Str [g/tex]	Elg [%]	Rd	+b	CGrd Upland	TrCnt	TrAr [%]	TrID TrGrd	Amt
01	158		9.2	3.90	0.86	29.55	85.8	6.8	32.6	4.9	72.6	10.8	33-1	17	0.26	2	584
02	144		9.1	3.89	0.86	29.00	83.8	7.9	31.2	5.1	73.1	10.8	33-1	28	0.48	4	580
03	146		8.8	4.16	0.87	29.66	85.2	6.8	29.6	5.1	73.6	10.9	22-2	27	0.45	4	632
04	139		8.9	4.09	0.87	29.50	83.9	7.5	29.3	4.9	73.1	11.8	23-1	17	0.28	3	587
05	151		8.8	3.81	0.86	29.41	86.2	6.3	28.7	5.4	73.7	11.4	23-1	18	0.20	2	595
n 5																	
Average	**148**		**9.0**	**3.97**	**0.86**	**29.43**	**85.0**	**7.1**	**30.3**	**5.1**	**73.2**	**11.1**	**23-2**	**21**	**0.33**	**3**	**596**
Std.Dev.	7		0.2	0.15	0.00	0.25	1.1	0.6	1.6	0.2	0.4	0.5		6	0.13		21.1
CV%	**5.0**		**2.0**	**3.7**	**0.5**	**0.9**	**1.3**	**9.0**	**5.2**	**3.7**	**0.6**	**4.1**		**26.1**	**38.3**		**3.5**
Q99% +/-	15		0.4	0.31	0.01	0.52	2.3	1.3	3.3	0.4	0.9	0.9		12	0.26		43.4
Min	139		8.8	3.81	0.86	29.00	83.8	6.3	28.7	4.9	72.6	10.8		17	0.20		580
Max	158		9.2	4.16	0.87	29.66	86.2	7.9	32.6	5.4	73.7	11.8		28	0.48		632

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