Extraction and Utilization of Textile Fibres From the Leaves of the Pineapple Plants.

By

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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Dedicated to my beloved husband Stephen Kariuki, and our two boys Mwaura and Kahugu.
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Given that vast quantities of pineapple leaves go into waste each year in Kenya, this study was carried out to investigate the possibility of extracting the fibre and to further analyze the quality of the fibre in comparison to other cellulosic fibres that are already in use in the Kenyan textile industry. About 1.1 kg of fibre was extracted using hand decorticating methods. The fibre tests that were carried out showed the fibre to be similar to flax in visual and longitudinal microscopic appearance, while the cross-sectional appearance is like that of sisal. The burning characteristics are similar to those of other cellulosic fibres in general. The moisture regain value of 10.39 is close to that of cotton which ranges from 7-12. However the tenacity of the fibre is lower than that of other cellulosic fibres, though slightly higher than that of regular rayon which is a regenerated cellulose fibre. The fibres were also spun using hand techniques, and a variety of textile articles made using various hand weaving techniques.
The pineapple plant "Ananas comosus" is a perennial monocotyledonous tropical plant, which belongs to the family Bromeliaceae. The plant has a very short main stem that produces a rosette of leaves which later elongate and bears numerous spirally arranged dark green sword shaped fibrous leaves (Kirby, 1963).

The fleshy part of the leaf can be removed to liberate a textile fibre. According to Pursglove (1972) the leaves of pineapple plant can yield between 2 and 3 percent of strong white silky fibre, 38-39 cm in length. The length however depends on the variety of the plant.

In general, textile fibres when classified according to origin fall under two main categories, namely: natural and man made fibres. Man-made fibres are made through the process of polymerization, whereby simple chemical elements (monomers) are put together to make complex chemical compounds (polymers). The fibre forming process is then completed by extrusion of the fibre forming substance through fine holes known as spinnerets. The jets of liquids are then hardened to form solid filaments.

According to Cook (1974) man-made fibres fall into
two main groups, depending on the origin of the fibre forming material from which they are made. These are the natural polymer fibres in which the fibre forming material is of natural origin, such as cellulose or protein. Examples of natural polymer fibres include rayons, which are based on regenerated cellulose, casein and groundnuts fibres which are examples of natural polymer fibres of protein origin. The second group is the synthetic fibres in which the fibre forming substance is manufactured. These include nylon, polyester and acrylics. (Cook, 1974)

The natural fibres on the other hand, can be divided into three main classes namely: vegetable fibres, animal fibres and mineral fibres (Cook 1974). Mineral fibres are those obtained from asbestos, glass or aluminium while animal fibres, which are also referred to as protein fibres, are either obtained from animal hairs, such as wool or from animal secretions such as silk. Vegetable fibres are obtained from various parts of plants. There are those that are derived from seed hairs and fruits, such as cotton, coir, and kapok, while others are derived from the stem bast and these are generally referred to as bast fibres. Examples of bast fibres are
flax, jute, hemp, kenaf and ramie. There are also those that are derived from the main vascular system of monocotyledonous plants, commonly referred to as leaf fibres. These include sisal, henequen, abaca (manila), pineapple and others. (Cook, 1974)

Agronomic Characteristics. The pineapple plant has a fibrous root system, which may penetrate up to around 0.6m below the surface of the soil, with most of the roots being found in the upper 0.3m. The central stem only grows to a height of 0.6m, and produces a rosette of leaves, that are arranged in a spiral manner. Propagation may be done by means of crowns from the top of the fruit, slips, which are leafy shoots that grow at the base of the fruit or suckers which are also leafy shoots that develop from the axil of the leaves on the lower part of the stem (Williams 1975).

At the tip of the stem, one inflorescence, which appears as a red bud, is produced 12-18 months after planting, depending on the type of planting materials used (Acland 1971). Under normal conditions, the fruit is ready for harvesting about 6 months after the bud appears.

After harvesting the first crop, a second crop,
(ratono crop) can be taken by allowing one or more suckers to grow on each plant. The ratoon crop is ready for harvesting about 12-14 months after harvesting the plant crop. The plant can continue producing fruit for several years, but the quality and size of fruit deteriorates with age. In Kenya, the plant crop is normally harvested 20 months after planting, and only one ratoon crop is harvested 14 months later, after which the plant is uprooted and the field cleared for replanting.

In clearing the fields, the plant residue can be left on the soil surface to dry and decay, or can be ploughed into the soil, especially in areas of high rainfall, in order to rot and build up organic matter as well as return valuable nutrients into the soil. This however may require the land to be left uncultivated for some time. The most commonly used method for clearing the fields is leaving the plants to dry and then they are burnt. The burning also helps to control the mealy bug which is the most serious insect pest in the growth of pineapples. However, burning destroys some of the minerals such as nitrogen, but others such as potassium remain. In some other areas, the old plant is simply discarded or fed to cattle.
The pineapple plant varies in height from 90-100 cm with a leaf spread of 130-150 cm. The active functioning leaves, about 25 to 30 per plant are long and thin, about 90-150 cm in height and 2-2.5 cm wide, and are tapered towards the tip (Estillo 1980).

The plant is hardy and can withstand considerable droughts. However for fast growth and good quality high yields a regular supply of moisture is essential. A well distributed annual rainfall of 1000 mm is minimum requirement for optimum growth. The pineapple plant is best adapted to porous well drained acid soils. For high yields heavy application of nitrogen is required. This is either applied as foliar spray or as soil applied fertilizer.

Pineapple varieties. The cultivated form of Ananas comosus are in different varieties. These include the smooth cayenne, red spanish, queen, and others. Some characteristics of these varieties, according to Williams (1975) are as follows:

- Smooth cayenne; This is the most important variety particularly for canning. The leaves are spineless and it is mostly grown in Hawaii, Africa and other areas.
- Red spanish; This is a hardy native variety with very
spiny leaves of high fibre content. It is mainly grown in Cuba and Puerto Rico.
Queen; The leaves are spineless and it bears small fruits.
According to Acland (1971) the smooth cayenne is the only variety grown in Kenya. As mentioned above, this variety is mainly cultivated for canning. However research done in the Bureau of Plant Industry, Fibre Laboratory division in the Philippines has shown that the smooth cayenne also provides durable raw materials for cloth weaving (Estillo 1980).

In Kenya pineapple is mainly grown in Thika where the Kenya Canners Limited is involved in growth and production of pineapple products in large scale. There are also small scale farmers in other parts of Central province, and in other provinces such as Coast, Eastern, Nyanza, Rift Valley and Western. In the year 1990, over 350,000 metric tonnes of the smooth cayenne variety was produced in Kenya (Ministry of Agric: Annual Report).

Statement of the Problem

In the growth of pineapple for commercial production, the old plant is uprooted after the harvest
of the first ratoon crop, about 35 months after planting. As stated above, the uprooted plant can either be allowed to decay, burnt or discarded. Can the leaves of the plant be processed into a textile fibre which can be put into use that can be of economic worth to the country?

If the quality of the fibre is found to be worthwhile, then the benefits achieved by decaying or burning the leaves, namely building up of organic matter, returning valuable nutrients into the soil, and destruction of pests can be achieved through other means such as use of fertilizers and pesticides to allow for large-scale production of the fibre given that over 7,000 hectares of land are being used for growth of pineapple in Kenya (Ministry of agric: Annual report 1990). There is evidence from review of literature that the fibre has been extracted and utilized to make textile articles for local consumption in countries such as Philippines, Formosa, China and Brazil (Kirby 1963). However there is no documentary evidence of any use of the fibre in Kenya.

Purpose of the Study

The purpose of this study therefore is to investigate the quality of the fibre obtained from the
leaves of the pineapple variety grown in Kenya.

Objectives of the Study
1. To extract textile fibres from pineapple leaves using hand methods.
2. To identify physical properties of the fibres.
3. To make yarns from the fibres using hand spinning methods.
4. To identify possible uses of the yarn using simple hand looms and hand weaving techniques.
5. Based on the findings recommendations will be made.

Significance of the Study
Review of literature has indicated that research has been done in other countries concerning the extraction and utilization of textile fibres from pineapple leaves. The fibre has been used for production of pina cloth, cordage thread, upholstery, fabric construction and other uses (Cook 1974, Estillo 1980). No such work has been done in Kenya. The findings of this study will therefore contribute to the body of knowledge in this area and will also facilitate further research in the area in order to explore the possibility of making full use of the fibre as in other countries, with the aim of boosting the
economy of the country. The findings will also contribute to the textile industry by providing a textile fibre whose potential can be further explored, with the aim of adding variety and quality of textile products.

Large-scale production of the fibre if found possible would also contribute towards providing employment. This is especially important bearing in mind the fast growing Kenyan population.

Scope and Limitation of the Study

For fibre production, special varieties of pineapple are grown at close spacing, preferably in a shade and the young fruits are removed soon after flowering so that the leaves may develop more fully (Purseglove 1972). Special growing of pineapple will not be undertaken in this study due to limitations of time and resources. The study will therefore confine itself mainly with the utilization of already matured pineapple leaves of the locally grown variety.

The research work will mainly be concerned with investigating the possibility of extraction and utilization of the fibre, and due to limitations of time and resources, the actual economic viability of the project will not be addressed to but will be recommended
for further research. The property testing will be limited to those tests that can be carried out using the available resources and facilities at the Kenya Bureau of Standards. To assess the usefulness of the fibre, the properties tested will be compared with those of other cellulosic fibres that are already in use in the textile industry where such information will be available. This comparative analysis will be used to conclude the research findings.

For machine spinning and fabric construction large quantities of fibre are required. However the time and resources available will not allow for production of large quantities of the fibre. This implies that the scope will not go beyond hand spinning and hand weaving. However, given the amount and quality of fibre that will be obtained, the possibility of making as many different articles as possible will be explored.

Due to possible wastage of fibre in the hand decorticating methods the percentage of fibre production per leaf may be low, in comparison to other method of extraction that may have been used in other countries.
Basic Assumptions

This research work was undertaken with the following basic assumptions:

1. That the researcher will be able to extract a reasonable quantity of fibre from pineapple leaves using the method described in the study.

2. That the fibre extracted can be spun and used in making articles of textile use.

Definition of Major Terms Used in the Study

1. Rosette - a cluster of leaves in clouded circles or spirals.

2. Inflorescence - A flower cluster, or a solitary flower that begins to bloom.

3. Ratoon - branches that grow out of the main stem that are capable of producing fruit.

4. Suckers - leafy shoots that develop from the axil of the leaves of the pineapple plant.

5. Axil - angle between a branch of the leaf and the axis from which it arises.

6. Crown - top leafy part of a pineapple fruit.

7. Slips - leafy shoot that grows at the base of the pineapple fruit.
8. Decortication - a mechanical process of removing the fleshy part of leaves to liberate fibres.

9. Spinning - a process of twisting fibres together to form yarn.

10. Loom - a frame or machine for interlacing at right angle two or more sets of thread or yarn to form a cloth.

11. Retting - keeping leaves submerged in water for a given length of time.

12. Pectin - a substance that binds cell walls in plant tissue.

13. Weaving - to form threads or yarns into materials by interlacing them on a loom.

14. Hand weaving - weaving with hands or without a loom.

15. Cordage - all kinds of ropes, lines, cords, and twines manufactured from natural or man-made fibres.

CHAPTER TWO

LITERATURE REVIEW

Due to the fact that little has been done in the extraction and utilization of pineapple leaf fibre in Kenya, most of the literature reviewed is based on work that has been done in other countries. According to Joseph (1981) cellulose fibres have several properties in common, therefore a general overview of work done on extraction and utilization of other fibres will also be useful in this study. Review of related literature will be divided into three sections for discussion purposes, namely (i) Extraction of the fibre (ii) fibre property testing and (iii) Fibre Usage.

Extraction of Fibre. Depending on the origin of vegetable fibres, each specific fibre requires a method of extraction which involves separating it from the part of the plant in which it is embedded. For example there are those fibres derived from the stem bast of dicotyledonous plants, and those derived from the main vascular system of monocotyledonous plants.

Flax is a bast fibre obtained from the stem of the flax plant. To obtain this fibre from the stalk, the woody portion must be rotted away. According to Cook (1974)
this is usually accomplished by a process referred to as retting, whereby the stems are subjected to the action of water, fungi and bacteria which decompose the woody part of the stem leaving the fibre bundles intact. Retting is followed by breaking and scutching to complete the process of extraction. Other bast fibres such as jute, hemp and kenaf are also extracted by the retting method, with an exception of ramie which is extracted by machine decortication (Joseph 1981).

Leaf fibres on the other hand are mainly extracted through decortication with or without prior retting. Sisal, an important leaf fibre that comes from the plant Agave Sisilana is mainly extracted by machine decortication (Lock 1962). However, where only small amounts are required extraction by hand is done. According to Kirby (1963) decortication should follow as soon as possible after cutting the leaves because the juices in the leaves tend to harden and become gummy, making extraction more difficult.

Cantala fibre, also from the sisal family is extracted from the leaves by a retting process, whereby the harvested leaves are cut into two or four pieces, and retted in salt water, or cut into many pieces and retted
in fresh water for a period of 8-14 days depending on the
time of the year when retting is done. Henequen, another
leaf fibre from the sisal family is extracted either by
hand or machine immediately after harvesting.

Abaca, or manila hemp is another example of leaf
fibres, which is obtained from *Musa textelis*, of the
banana family. The fibres are extracted by hand methods,
a mechanised form of hand stripping, or machine
decortication (Kirby 1963).

Another example of leaf fibre is the Sansevieria,
from the lily family. Some species of the fibre are
extracted by placing on a wooden board and scraping with
a blunt knife, while others are extracted by pounding
with a mallet and then retting in water for about 2 weeks
(Kirby 1963).

The pineapple leaf fibre has been extracted using a
variety of methods in different countries. These methods
include chemical methods, enzymatic action, mechanical
means and retting. In Japan, extraction of pineapple
leaf fibre has been done, mainly for paper production.
Fujishige, Norinaga, Tsubo, Hiroshi, Kobayashi, Yoshuo,
Matsuo, Ryukichi, Nashiyama, and Masashi, (1977) from the
agency of Industrial Science and Technology, carried out
extraction of the fibre using enzymes. The leaves were immersed in a 1% aqueous enzyme (cellulose) at PH 4-6 and 40°C for 5 hours to give the fibre. In the same Agency, Fujie, Nobunaga, Tsuboi, and Koji, (1978), extracted crude fibres from pineapple with water to remove pectin. The crude fibres were immersed in flowing water at 30°C for 10 days and treated in two litres water at 100°C for 8 hours, to extract the fibre.

In Britain, a study by Sen, Swapan and Kumar (1982) indicates that fibres prepared for textile use are prepared by extracting the fibre from pineapple leaves by decortication, and then treated for 10 minutes at controlled pressure (1-5 atm) at 80-100 degrees centigrade with a solution containing 0.1-10% nonoic detergent and 0.2-3% sulphuric acid, with a volume ratio between solution and fibre maintained at 10:1. The fibres are then washed with water to remove the gum and then neutralized with sodium or calcium hypochloride solution.

In the Philippines, the growth of pineapple was started in 1558, and pina cloth was first made by about 1570 (Purseglove 1972). This is an indication that extraction and utilization of the fibre was started
hundreds of years ago. However it was not until recently that there has been a challenge to adapt the old historic craft methods, to modern factory methods so that production can be scaled up to a valuable contribution to the countries economy.

A report by Estillo (1980) on a research work undertaken by the Philippines Textile Research Institute, later referred to as (PTRI), explains the development efforts on fibre extraction and mechanical processing of pineapple leaf fibre into cloth, with the ultimate goal of optimising the fibre properties as well as the yield, to bring down the cost and improve the quality of the fibre intended for commercial textile application.

The extraction methods used by PTRI included:— (i) Decortication, which was done by use of motorised machines. The fibres are then washed and dried in the shade. (ii) Microbial retting — which involved immersing the decorticated fibre bundle in water for 5-12 days. This could also be accomplished in 26 hours by introducing a pure culture of micro-organisms. The retting process helps to free the fibre from the binding tissues which are mostly of pectic nature due to the action of micro-organisms. After retting, the fibres
were washed under running water and allowed to dry.

(iii) Chemical degumming - This was aimed at further reduction of the gum content to obtain readily spinnable fibres. This was accomplished by subjecting the fibres to a dilute solution of alkali at elevated temperature in the absence of air. This process separates the individual fibres, without affecting their strength or other characteristics. This was then followed by a process of mechanical and chemical softening, followed by a one week ageing period, after which the fibres were ready for use.

According to Kirby (1963) pineapple leaf fibre is extracted either by mechanical means, or retting process. The mechanical method involves the use of a handstripping device made of bamboo. A piece of bamboo with 3 nodes, about 3 ft long and 2" wide is used to make the device. An opening is made on the stick, and a strip of leaf is put into the opening and held firmly by pressing a wedge fitted for that purpose. The stripper then pulls the leaf, holding the base end. The strip is then reversed and pulled in the same way to complete the cleaning process. However, in this method, only the strongest fibres are obtained, while the weak
fibres break off and become waste.

Another mechanical method involves cutting the leaf into strips, and removing the outer covering which encloses the fibre from the upper and lower surfaces, using a blunt knife, enabling the scraping to be done faster. The leaf is then placed on a wooden block and scrapped using a smooth edge of a broken porcelain plate, after which the fibres are washed and dried.

In the retting process on the other hand the leaves are made into strips, and the outer covering removed as is described above. The leaves are then held together into small bundles of about 2" in diameter at the larger end; and then into bigger bundles which are tied together loosely. The bundles are then immersed in retting water, with the help of weights placed on top. Where available, slow running water is preferred to prevent discoloration of the fibre, and also emission of bad smells from the retting liquor. The retting period varies between 5-10 days depending on the type of leaves, and temperature of water.

After retting, the fibre is washed and cleaned, by holding one small bundle at a time at one end and rinsing downward so that decomposed matter is washed out. The
fibres are then dipped in water and shaken to remove any more extraneous matter remaining. The fibres are then hang in the shade to dry.

Other countries where extraction for pineapple fibre by mechanical means has been done include Formosa, Java, Spain, China, Taiwan and Brazil. In these countries the fibre has been used for making fabric, lace, ropes, fishing lines and nets, and also for embroidery. (Kirby 1963). The same report by Kirby also continues to say that in Kenya, decortication attempts were made on pineapple leaves using an ordinary sisal decorticator and it was found that the leaves were decorticated well, with very little fibre loss in the machine. However, the leaves used here were about 3 ft long, which is longer than the average length of pineapple leaves.

Fibre property testing. According to Miller (1968) natural fibres are produced in a range of qualities due to variable growing conditions which prevent uniformity. This is an indication that even fibres from the same origin can differ in quality depending on the conditions that the plant has been subjected to in the process of growth. Hall (1969) on other hand indicates that for a textile fibre to be really useful and important, it
must have some properties which enable it to be converted into yarn for use.

Fibre property testing is therefore important, in order to ascertain the quality, and whether or not the fibre can be put into textile use. Some of the properties that are important in textile fibres according to Hall (1969) include:-

1. Shape, which includes length, thickness, shape of cross-section and straightness.

2. Strength - the strength of individual fibres govern the strength of the yarn, and consequently that of the end products. Strength must also be accompanied by pliability and tenacity for the fibre to be useful.

3. Softness - for tapestry, upholstery and cordage work, it is often an advantage that the textile fibre be stiff and resilient.

4. Density, which determines the volume of fibre for any given weight. It is possible to produce fabric having a full solid appearance more cheaply with low density yarns than with more dense yarns.

5. Moisture - the power of textile material to absorb water influences the kind and variety of uses to which it can be put. A material with poor affinity for
water is likely to be difficult to dye and is also uncomfortable to wear.

Other properties include lustre, solubility in aqueous and organic solvents, extensibility and elasticity, all of which have a bearing on the quality of the end products of individual fibres.

According to American society for testing materials standards requirements (ASTM D1776 (1989)), all testing of textile materials should be carried out under standard conditions of relative humidity and temperature. These are specified as $65 \pm 2\%$ relative humidity, and $21 \pm 2^\circ$C. This is an important practice as it ensures reproducible test results on textiles and textile products. Results of tests carried out under uncontrolled atmospheric conditions may not be comparable with each other. This is mainly due to the fact that many of the properties of textile materials are influenced by relative humidity and temperature conditions to which the textile material is subjected prior to and during testing.

Cobley (1970) indicates that pineapple leaf fibres are very strong and durable. They are shining white when extracted, flexible and of high quality and are damaged by water. The same report by Cobley also suggests that
fibre from the leaves are lustrous and would probably be used as a substitute for flax. Cook (1974) also describes the fibre as soft, white and good lustre, strong and also hardwearing, while Joseph (1981) adds that the fibre is about 2-4 inches in length light ivory coloured fine, lustrous, flexible and strong with high resistance to water. Estillo (1980) of the Philippines Textile Research Institute confirms most of the above stated properties, on strength, colour fineness and lustre. However, Estillo notes the length as 7.5 to 10 cm while Purseglove (1972) says the length is 38-39 cm. According to the above mentioned authors therefore, the pineapple leaf fibre has been found to be strong and hard wearing, white in colour, soft and flexible and lustrous. However, on length, contrasting figures have been given, ranging between 5-39 cm.

Usage. Leaf fibres in general are coarser than bast or seed fibres. They are actually classified generally as hard fibres. According to Cook (1974) these fibres are often of great commercial value and are mainly used for making ropes and cordage, and also for production of textile fibres. Lock (1962) also confirms that a high percentage of hard fibres is used for making
agricultural twines and other cordage work. Sisal for example has been used for making carpets, bags, matting upholstery and padding, while henequen is mainly used for agricultural twines. Abaca is used for ropes, and cordage, placemats for outdoor and indoor use and for clothing. Pineapple leaf fibre has been put into various uses in different countries. In Japan, the fibre has been extracted and used for paper production. The fibre has also been produced for textile use in Britain. In Philippines and Formosa, a study by Cobley (1970) shows that pineapple leaf fibres are made into a good quality cloth, known as pina cloth which is rather like linen and with a silky sheen. Purseglove (1972) indicates that pina cloth was first made in the year 1570.

Other uses include cordage and threads. A more recent research in the Philippines has indicated that the fibres can be spun and woven or knitted into fabrics. Blending with other fibres such as pineapple/acrylic 35/65 has also been found possible.
CHAPTER THREE

METHODOLOGY RESULTS AND DISCUSSIONS

The methods used in (a) extraction of the fibre, (b) fibre tests, and (c) spinning and weaving will be described in this chapter. A brief discussion of the results will be given under each method where appropriate, but a general discussion of all the result will be given at the end of the chapter.

Extraction of the Fibre

Fresh pineapple leaves were obtained from Delmonte Canning Industry in Thika. The leaves were obtained from already matured pineapple plants, shortly after the harvest of the second ratoon crop, which was about 35 months after planting. This was done by uprooting the whole plant, and then detaching the individual leaves by hand. A bundle of two to six leaves of equal lengths was held together by the tip end with one hand and the butt end was placed on a flat smooth stone. Using a wooden mallet, the leaf bundle was pounded gently using the free hand. The pounding was continued along the whole length of the leaf bundle. This loosened the leaf matter considerably. The bundle was then tied loosely in the middle and held over running water to wash away the
loose leaf matter. The undetached leaf matter was removed by scraping off with a blunt knife on a smooth surface under running water. The water helped to wash away the leaf matter immediately it was scrapped off leaving the fibre bundle clean. These clean fibres were rinsed by shaking the bundle in water while holding it at the middle. The clean fibres were hung in a shade to dry for about two days while still tied in small bundles.

Results and discussions. The fibres obtained were white in colour, and appeared shining white when in water. A total of about 1.1kg of fibres was obtained. In the process of scrapping off the extraneous leaf matter, some of the fibres were cut off and ended up as waste. However, it was observed that gentleness in pounding and scrapping helped to reduce the degree of fibre wastage.

Determination of Percentage Fibre Yield

Procedure. Four leaf bundles of two to six leaves each were taken. The mass of each bundle was determined and the fibres extracted according to the procedure described above. The fibres obtained were conditioned in a standard atmosphere for textile testing (65 ± 2% relative humidity and 21 ± 2 C) after which the mass of
each sample was taken and recorded.

Results. The table below shows (a) the number of leaves in each sample, (b) the fresh mass of the leaves, (c) the standard mass of the fibres and (d) the corresponding percentage yield where the fresh mass of leaves represent mass of the leaves as they were obtained from the plantation, and the standard mass of the fibre represents the mass taken after conditioning the fibres.

Table I: Determination of the percentage fibre yield of the pineapple leaves.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Number of leaves</th>
<th>Fresh mass of leaves in gm</th>
<th>Standard mass of fibres in gm</th>
<th>% yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>77.00</td>
<td>1.4402</td>
<td>1.87</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>138.10</td>
<td>2.0964</td>
<td>1.51</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>168.30</td>
<td>2.8979</td>
<td>1.73</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>249.90</td>
<td>4.0796</td>
<td>1.63</td>
</tr>
</tbody>
</table>

The average % yield is given by: \((1.87 + 1.51 + 1.73 + 1.63)/4\)

Discussion. From the table above the average yield of the fibre is about 1.7%. However the fresh mass of the leaves is dependent on (a) the time taken between uprooting of the plant and the weighing of the sample, and (b) the moisture conditions of the plantation, whereby in moist and humid conditions the leaves are
likely to weigh more than in dry conditions due to differences in the moisture content of the leaves. In this study fibres were obtained from the field when the conditions were rather dry. Therefore, the percentage fibre yield of (1.7%) can only be considered as an estimate.

Fibre Tests

All the fibre tests in this section were carried out at the Kenya Bureau of Standards textile quality control laboratory where the atmospheric conditions necessary for textile testing, as explained in chapter two, were provided. A few fibre bundles were picked at random to make about 100g, and this was used as the laboratory sample. The following fibre tests were carried out:

Microscopical examination
Burning tests
Length
Moisture content and regain
Billighames tests
Drying twist test
Ash characteristics
Breaking tenacity (wet and dry)
Elongation at break (wet and dry)
The significance of each of the above mentioned tests is briefly discussed below.

According to Tylor (1972) the microscopical and burning tests are mainly important for identification of a fibre. Tortora (1987) also indicates that the behaviour of a fibre towards heat is also important as it helps determine the way in which a fibre must be handled during processing, use and care. The length of a fibre on the other hand helps to determine the spinnability of the fibre. The amount of moisture which a fibre is capable of absorbing and retaining has an effect in the value of the fibre since it influences such fabric qualities as (a) the comfort of the wearer, (b) the degree of shrinkage that may occur during laundering and (c) the speed of drying after laundering (Tylor 1972). Siegert (1976) also suggests that the dimensional stability and dyeability of a fibre is also affected by its moisture content and regain properties.

As indicated by Textile Institute (1970), various cellulosic fibres behave differently when subjected to the Billighames and drying twist tests and that the ash characteristics of the various fibres also differ. The importance of these three tests in this study therefore
is to provide a basis for comparison of the pineapple leaf fibre with other cellulosic fibres and at the same time provide information that can aid in identification of the pineapple leaf fibre. The tensile properties of a fibre are the most important qualities in determining the textile use of a fibre. According to Hollen (1988) the strength of a fibre affects such fabric qualities as durability, tear strength, sagging and pilling, while elongation also affects the tear strength and reduces brittleness. For cordage fibre the strength determines the durability and efficiency of the end use products. The test standard or the source of information that was adopted for the procedure is quoted under each test.

Microscopic Examination

Both the longitudinal and cross-sectional view of the fibre were examined.

Procedure. (I) For the examination of the longitudinal section, a single strand of fibre was placed on a microscope slide and a drop of liquid paraffin (mountant) was added. The cover glass was placed over the fibre and pressed lightly to eliminate air bubbles. The slide was then carefully placed on the microscope stage and the fibre was observed and the features noted.
The features observed are shown in figure 4.

(II) For the cross-sectional view, a single strand of fibre was suspended vertically by hand with the free end of the fibre touching the bottom of a cylindrical rubber container. Melted paraffin wax was poured into the rubber container. The fibre was held in position until the wax solidified, firmly embedding the fibre, as shown in figure 1 below.

Fig. 1: Pineapple Fibre Embedded in Wax.
The rubber container was pressed on the sides gently to release the cylindrical shaped wax with the fibre embedded in the middle. (Fig. 2)

Fig. 2: Removal of the fibre embedding wax.

Using a microtome the wax was sliced in cross-section to expose the cross-sectional view of the fibre as shown in figure 3. The section was mounted on the microscope
and the fibre section brought to focus. A magnification of 100, and then 200 was used, and the features observed. (Textile Institute 1970).

Fig.3: Sliced cross-section of wax, exposing the fibre cross-section.

Results. In the longitudinal view, cross markings and striations were noticed along the length of the section under observation as shown in figure 4.
Fig 4: The longitudinal view of a pineapple fibre as viewed under a microscope.

In the cross-sectional view, a crescent shaped outline, with polygonal shapes within was seen as shown in figure 5.

(Not drawn to scale)
Burning Tests

The aim of these tests was to investigate the reaction of the fibres to heat and flame.

Procedure. (i) A tuft of fibres was held by a pair of forceps and was slowly brought close to but not into a small non-luminous flame, and the reaction of the fibres to heat noted.
(ii) Another tuft of fibres was held as in (i) above, and brought right into a non-luminous flame, and the burning characteristics noted.

(iii) Another tuft of fibres was placed close to a crystal of potassium nitrate on a metal plate. The temperature of the plate was raised using an electric heating plate until the crystal melted, (between 337 and 339°C). The burning behaviour was observed (Textile Institute 1970).

Results. The behaviour of the fibre specimens, when approaching flame, in the flame, and when on the hot plate have been presented in table 2.

Table 2: Burning test results of pineapple leaf fibres.

<table>
<thead>
<tr>
<th>Behaviour of specimen</th>
<th>Approaching flame</th>
<th>In flame</th>
<th>On hot plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>The fibres did not melt or shrink away from the flame.</td>
<td>The fibres burned readily with a yellow flame, emitting the smell of burning paper. A small amount of greyish ash was left.</td>
<td>The fibres charred below 337°C. They did not melt.</td>
<td></td>
</tr>
</tbody>
</table>
Length of fibres

The aim of this test was to determine the length distribution of the pineapple leaf fibres.

Procedure. One hundred single fibres were drawn at random, and each fibre was straightened out carefully over a metre ruler. The length was measured in centimetres and recorded. (Morton and Hearle (1975).

Results. In order to give a comprehensive picture of the distribution of lengths of fibres from pineapple leaves, the length data obtained was presented in a grouped frequency distribution, (table 3) and a graphic representation of the grouped frequency data (figure 6).
Table 3. Frequency table of grouped pineapple fibre lengths, with computation for mean (M) and median (MD) lengths, and standard deviation.

<table>
<thead>
<tr>
<th>Length in cm. (class intervals)</th>
<th>freq. (f)</th>
<th>cum. freq.</th>
<th>mid-pt (x)</th>
<th>$x^2$</th>
<th>fx</th>
<th>f($x^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70-72</td>
<td>1</td>
<td>100</td>
<td>71</td>
<td>6084</td>
<td>71</td>
<td>6084</td>
</tr>
<tr>
<td>67-69</td>
<td>1</td>
<td>99</td>
<td>68</td>
<td>4624</td>
<td>68</td>
<td>4624</td>
</tr>
<tr>
<td>64-66</td>
<td>0</td>
<td>98</td>
<td>65</td>
<td>4225</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>61-63</td>
<td>5</td>
<td>98</td>
<td>62</td>
<td>3844</td>
<td>310</td>
<td>19220</td>
</tr>
<tr>
<td>58-60</td>
<td>4</td>
<td>93</td>
<td>59</td>
<td>3481</td>
<td>236</td>
<td>13924</td>
</tr>
<tr>
<td>55-57</td>
<td>7</td>
<td>89</td>
<td>56</td>
<td>3136</td>
<td>392</td>
<td>21952</td>
</tr>
<tr>
<td>52-54</td>
<td>8</td>
<td>82</td>
<td>53</td>
<td>2809</td>
<td>424</td>
<td>22472</td>
</tr>
<tr>
<td>49-51</td>
<td>6</td>
<td>74</td>
<td>50</td>
<td>2500</td>
<td>300</td>
<td>15000</td>
</tr>
<tr>
<td>46-48</td>
<td>7</td>
<td>68</td>
<td>47</td>
<td>2209</td>
<td>329</td>
<td>15463</td>
</tr>
<tr>
<td>42-45</td>
<td>7</td>
<td>61</td>
<td>43</td>
<td>1849</td>
<td>301</td>
<td>12943</td>
</tr>
<tr>
<td>40-42</td>
<td>5</td>
<td>54</td>
<td>41</td>
<td>1681</td>
<td>205</td>
<td>8405</td>
</tr>
<tr>
<td>37-39</td>
<td>6</td>
<td>49</td>
<td>38</td>
<td>1444</td>
<td>228</td>
<td>8664</td>
</tr>
<tr>
<td>34-36</td>
<td>4</td>
<td>43</td>
<td>35</td>
<td>1225</td>
<td>140</td>
<td>4900</td>
</tr>
<tr>
<td>31-33</td>
<td>9</td>
<td>39</td>
<td>32</td>
<td>1024</td>
<td>228</td>
<td>9216</td>
</tr>
<tr>
<td>28-30</td>
<td>12</td>
<td>30</td>
<td>29</td>
<td>841</td>
<td>348</td>
<td>10092</td>
</tr>
<tr>
<td>25-27</td>
<td>5</td>
<td>18</td>
<td>26</td>
<td>676</td>
<td>130</td>
<td>3380</td>
</tr>
<tr>
<td>22-24</td>
<td>7</td>
<td>13</td>
<td>23</td>
<td>529</td>
<td>161</td>
<td>3703</td>
</tr>
<tr>
<td>19-21</td>
<td>6</td>
<td>6</td>
<td>20</td>
<td>400</td>
<td>120</td>
<td>2400</td>
</tr>
</tbody>
</table>

From the grouped frequency distribution, the modal length is 29 cm. The lengths of the fibres range between 70 cm. and 20 cm. The median (md) length is given by

$$L + \frac{(-n-c)i}{2f}$$

where $L =$ lower class limit of class containing median.
$n =$ number of fibre.
$c =$ cumulative frequency of the class below the
median class. 
i = class interval 
f = frequency of class containing median. 

\[ \text{md} = 39.5 + \frac{(50 - 49)}{3} \times 5 \]
\[ = 39.5 + 0.6 \]
\[ = 40.10 \text{ cm} \]

The mean length \((m)\) is given by \(\frac{fx}{n}\)

\[ = \frac{4051}{100} \]
\[ M = 40.51 \text{ cm} \]

The standard deviation \((s)\) is given by \(\sqrt{\frac{\sum f(x) - (\sum fx)}{n}}\)

\[ S = \sqrt{\frac{182442 - 164106}{100}} \]
\[ = \frac{\sqrt{18336}}{\sqrt{100}} \]
\[ = \sqrt{183.36} \]
\[ = 4.26 \]

\[ S = 4.26 \]

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Discussions. The length of the fibres ranged between 70 and 20 cm. The median length was 40.10 cm, while the mean length was 40.51 cm, with a standard deviation of 4.26. The wide range in length could be due to the possible arrangement of fibres in the leaf profile (as shown in figure 7), whereby the fibres that ran from
the base to the tip were longer than those from the sides of the leaf. The very short fibres, (less than 20 cm) were likely to have been scrapped off in the extraction process.

Fig 7: Diagram of a pineapple leaf to show the possible arrangement of fibres in the leaf profile.

From the graph in figure 6, the best fit line is in agreement with the arrangement of fibres in the leaf profile (figure 7), whereby the shorter fibres appear to be more in number than the long ones.

Moisture Content and Regain

The aim of this test was to determine (i) the
percentage of moisture contained by a fibre sample at moisture equilibrium in a standard atmosphere for textile testing (moisture content) and (ii) the percentage moisture regained by a dry sample of pineapple leaf fibres when placed in a standard atmosphere for textile testing until it reaches moisture equilibrium. Kenya Standard, Ks 08 264: (1981) giving the method for estimation of moisture in textile materials was adopted and used.

**Procedure.** The mass of each of two clean dry weighing bottles (with covers) was taken and recorded. A fibre sample of approximately 3g was placed in each bottle and the combined mass of bottle, cover and sample was taken and recorded. The bottles with samples in, were placed in an oven set at 110°C (with covers removed) and dried to a constant mass, after which they were cooled in a desiccator. The bottles were then carefully covered and quickly transferred onto a weighing scale and the combined dry mass of bottle, cover and sample was taken and recorded.

**Results.** The two sets of readings obtained were recorded in the table(4) below.

1

42
Table 4: Mass readings (in grams) of bottle, cover and fibre sample before and after drying.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>64.1227</td>
<td>67.2566</td>
<td>66.9660</td>
<td>3.1339</td>
<td>2.8433</td>
</tr>
<tr>
<td>b)</td>
<td>56.4533</td>
<td>59.0576</td>
<td>3.1543</td>
<td>2.8522</td>
</tr>
</tbody>
</table>

Moisture content (c) was given by:

\[ C = \left( \frac{a - b}{a} \right) \times 100 \]

Where:
- \( a \) = original mass of sample in gm
- \( b \) = oven dry mass of sample in gm

For sample a:-

\[ C = \left( \frac{3.1339 - 2.8433}{3.1339} \right) \times 100 \]

\[ = \left( \frac{0.2906}{3.1339} \right) \times 100 \]

\[ = 9.27\% \]

Moisture content = 9.27\%

For sample b:-

\[ C = \left( \frac{3.1543 - 2.8522}{3.1543} \right) \times 100 \]

\[ = \left( \frac{0.3021}{3.1543} \right) \times 100 \]

\[ = 9.58\% \]

Average moisture content value is given by \( 9.27 + 9.58 \)

\[ = \left( \frac{9.27 + 9.58}{2} \right) = 9.43\% \]
Moisture regain \((r)\) was given by the formula
\[
r = \frac{(a - b)}{b} \times 100\quad \text{where} \quad a \quad \text{and} \quad b \quad \text{represent the same values as in moisture content formula above}
\]
Sample a:-
\[
r = \frac{(3.1339 - 2.8433)}{2.8433} \times 100
\]
\[
= \frac{0.2906}{2.8433} \times 100
\]
\[
= 10.22\%
\]
Sample b:-
\[
r = \frac{(3.1543 - 2.8522)}{2.8522} \times 100
\]
\[
= \frac{0.3021}{2.8522} \times 100
\]
\[
= 10.59\%
\]
Average moisture regain value was given by
\[
\frac{10.59 + 10.22}{2} = 10.40\%
\]

Billighames Test

When subjected to this test, most leaf fibres, such as sisal, jute and ramie acquire a yellow colour, while abaca acquires an orange colour, (Textile Institute 1970). The aim of this test therefore was to investigate the behaviour of the pineapple leaf fibre, for the purpose of comparison with the above mentioned fibres.

Procedure. A fibre sample was washed in methylene chloride solvent in order to remove any present oil. The
sample was allowed to dry and then boiled in 5% nitric acid for 10 minutes, after which it was washed in water and then immersed in 0.25N sodium hypochlorite solution for ten minutes, then removed and dried. Any change in colour was observed and recorded. (Textile Institute 1970).

Results and Discussion. The fibre sample assumed a yellow colour. This behaviour was found to be consistent with that of other leaf fibres.

Drying-Twist Test

The aim of this test was to determine the direction of movement of the free end of a wet strand of fibre, when allowed to dry. As indicated by Textile Institute, (1970) when subjected to this test, flax moves in a clockwise direction, while hemp sisal, jute and urena move in a counter clockwise direction. The results of this test were used to compare the behaviour of the pineapple leaf fibres with the cellulosic fibres mentioned above. The information is also important for identification of the pineapple fibre.

Procedure. A strand of pineapple fibre was drawn and soaked in water for two minutes, after which it was
withdrawn and held over an electric hot-plate with a pair of forceps. The direction of twist as the fibre dried was observed and recorded.

Results and discussions. The pineapple fibre twisted in a counter clockwise direction. The behaviour was consistent with that of other leaf fibres.

Examination of Fibre Ash

According to Textile Institute (1970), when vegetable fibre ash from various fibres is observed microscopically, it shows various shapes of crystals, and these can be used for identification of the fibre. The aim of this test therefore was to examine the shape of the pineapple fibre ash particles under a microscope.

Procedure. A small tuft of fibre was allowed to burn and the ash was collected on a piece of mica. The ash was carefully transferred onto a microscope slide, and a cover glass was placed over the ash. A drop of water was used as a mountant and the ash particles were observed under a microscope.

Results. Rod-like structures were observed, as shown in figure 8.
Fig 8: Rod like structures seen when pineapple leaf fibre ash was observed under a microscope.

(Not drawn to scale)

Breaking Tenacity and Elongation (wet and dry)

The aim of these tests were:-

(i) to determine the mean breaking load per denier, and percentage Elongation at break of the pineapple fibre; and ii) to compare the breaking tenacity and elongation at break for dry and wet fibres.

Procedure. (i) A fibre sample specimen in the form of
2 to 3 fibre strands held together, was straightened out and the length measured. A uniform length of 30 cm. was used for all the 19 specimens. The weight of each specimen was taken and the readings recorded.

A constant rate of traverse (C.R.T.) tensile testing machine (model zwick 1435) was set to obtain a nominal gauge length of 100 mm and a traverse speed of 100 mm/min. Each test specimen was mounted between the jaws of clamps, in such a way as to remove slack, without stretching the specimen. The machine was started, and the specimen was pulled to breaking point. The breaking load, (in gram force) and the elongation at break (in percent) were recorded.

(ii) A similar set of 18 specimens were used for testing the wet breaking tenacity and elongation at break. Each specimen was immersed in 0.1% Tinovetin J.U. wetting agent, for 30 seconds, and mounted between the jaws of the machine clamps, as described above. The testing procedure was repeated, and the breaking load and elongation at break figures for the wet fibres were also recorded.

Calculations. The denier of each strand (weight in grams of 9000 m of fibre) was calculated using the formula
denier = Weight in g x 9000/length in m

The breaking tenacity in gram/denier (g/d) was obtained using the formula

\[
\text{breaking tenacity} = \frac{\text{Breaking load in g/denier of strand}}{}.
\]

Results. The weight, breaking load, elongation and breaking tenacity of each fibre strand for the dry and wet specimens were recorded in table 5 and 6 respectively.
Table 5: Breaking tenacity and elongation at break of the dry pineapple fibres.

<table>
<thead>
<tr>
<th>Wgt in gm of a 30cm fibre strand</th>
<th>denier of strand</th>
<th>breaking load in gm</th>
<th>breaking tenacity in gm/denier</th>
<th>elong. at break in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0049</td>
<td>147</td>
<td>260</td>
<td>1.76</td>
<td>1.52</td>
</tr>
<tr>
<td>0.0060</td>
<td>180</td>
<td>432</td>
<td>2.40</td>
<td>1.89</td>
</tr>
<tr>
<td>0.0032</td>
<td>96</td>
<td>160</td>
<td>1.67</td>
<td>1.60</td>
</tr>
<tr>
<td>0.0078</td>
<td>234</td>
<td>712</td>
<td>3.04</td>
<td>1.80</td>
</tr>
<tr>
<td>0.0056</td>
<td>168</td>
<td>384</td>
<td>2.29</td>
<td>1.62</td>
</tr>
<tr>
<td>0.0071</td>
<td>213</td>
<td>446</td>
<td>2.61</td>
<td>1.95</td>
</tr>
<tr>
<td>0.0065</td>
<td>195</td>
<td>456</td>
<td>2.34</td>
<td>1.93</td>
</tr>
<tr>
<td>0.0047</td>
<td>141</td>
<td>280</td>
<td>1.99</td>
<td>1.71</td>
</tr>
<tr>
<td>0.0060</td>
<td>180</td>
<td>476</td>
<td>2.64</td>
<td>1.83</td>
</tr>
<tr>
<td>0.0036</td>
<td>108</td>
<td>300</td>
<td>2.78</td>
<td>1.82</td>
</tr>
<tr>
<td>0.0050</td>
<td>150</td>
<td>328</td>
<td>2.18</td>
<td>1.98</td>
</tr>
<tr>
<td>0.0055</td>
<td>165</td>
<td>428</td>
<td>2.59</td>
<td>1.82</td>
</tr>
<tr>
<td>0.0044</td>
<td>132</td>
<td>268</td>
<td>2.03</td>
<td>1.57</td>
</tr>
<tr>
<td>0.0046</td>
<td>138</td>
<td>232</td>
<td>1.68</td>
<td>1.64</td>
</tr>
<tr>
<td>0.0061</td>
<td>183</td>
<td>444</td>
<td>2.43</td>
<td>2.08</td>
</tr>
<tr>
<td>0.0057</td>
<td>171</td>
<td>540</td>
<td>3.15</td>
<td>2.00</td>
</tr>
<tr>
<td>0.0036</td>
<td>108</td>
<td>276</td>
<td>2.56</td>
<td>2.00</td>
</tr>
<tr>
<td>0.0035</td>
<td>105</td>
<td>276</td>
<td>2.62</td>
<td>2.20</td>
</tr>
<tr>
<td>0.0032</td>
<td>96</td>
<td>184</td>
<td>1.91</td>
<td>1.70</td>
</tr>
</tbody>
</table>

From Table 5, the breaking tenacity of the pineapple leaf fibres is 1.70 - 3.0g/d. With a mean of 2.35g/d, a standard deviation of 0.4 and the coefficient of variation of 2.1%. The mean elongation at break is 1.82% with a standard deviation of 0.18 and a coefficient of variation of 0.94%.
Table 6: Breaking tenacity and elongation of wet pineapple leaf fibres.

<table>
<thead>
<tr>
<th>Wgt in gm of a 30cm fibre strand.</th>
<th>denier of strand</th>
<th>breaking load in gm</th>
<th>breaking tenacity in gm/denier</th>
<th>elong. at break in %</th>
</tr>
</thead>
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<td>237</td>
<td>420</td>
<td>1.77</td>
<td>2.19</td>
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<td>348</td>
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<td>1.91</td>
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<td>1.64</td>
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<td>504</td>
<td>2.02</td>
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<td>1.98</td>
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<td>1.86</td>
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<td>1.64</td>
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<td>1.92</td>
<td>2.15</td>
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<tr>
<td>0.0072</td>
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<td>376</td>
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<td>1.79</td>
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<tr>
<td>0.0032</td>
<td>96</td>
<td>180</td>
<td>1.87</td>
<td>1.97</td>
</tr>
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</table>

From table 6, the breaking tenacity of the wet fibres is 1.3-2.3 g/d with a mean of 1.80 g/d, a standard deviation of 0.23 and a coefficient of variation of 1.27%. The mean elongation was 1.97% with a standard deviation of 0.21 and a coefficient of variation of 1.16%. Table 7 gives a summary statistics for breaking tenacity and elongation for dry and wet fibres from table 5 and 6.

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Table 7: Summary statistics for breaking tenacity and elongation for dry and wet pineapple fibres.

<table>
<thead>
<tr>
<th>sample</th>
<th>mean breaking tenacity in g/d</th>
<th>standard deviation</th>
<th>mean elong. at break in %</th>
<th>standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>dry</td>
<td>2.40</td>
<td>0.40</td>
<td>1.82</td>
<td>0.18</td>
</tr>
<tr>
<td>wet</td>
<td>1.80</td>
<td>0.23</td>
<td>1.97</td>
<td>0.21</td>
</tr>
</tbody>
</table>

From table 8 above, there is a 25% decrease in breaking tenacity in the wet fibres, given by the formula

\[
100 \frac{(a - b)}{a}, \text{ where } a = \text{mean breaking tenacity of dry fibres} \\
\quad b = \text{mean breaking tenacity of wet fibres}
\]

\[
= \frac{(2.4 - 1.8)}{2.4} \times 100 \\
= 25%
\]

There is also a 8.24% increase in the elongation at break in the wet fibres given by:

\[
a \frac{(w - y)}{w} \times 100 \quad \text{where } w = \text{mean of elongation of wet fibres} \\
\quad y = \text{mean of elongation of dry fibres}
\]

\[
= \frac{(1.97 - 1.82)}{1.82} \times 100 \\
= 8.24%
\]
Spinning and Weaving

About 800g of the fibre was used for making 2 ply yarns of different thicknesses. Traditional hand spinning techniques were used, which involved plying, twisting and joining small bundles of fibres on a smooth surface. Hand weaving, hand knitting and crocheting techniques were used to make samples of variety of articles, which included 2 shopping bags, 2 table mats, a wall hanging and a chair cover. In order to provide variety, and to give an aesthetic touch to the articles made, some of the fibres were dyed to different colours before spinning. Photographs of these articles are shown in plates 1-XII. A brief explanation of the method used for making each article is given under each plate.
SPURN YARN: Made from pineapple fibre.

ROPE: Made using the fibres and hand weaving techniques.
PLATE III

SCHOOL BAG: Made using a crochet needle.

PLATE IV

SHOPPING BAG: Made fusing traditional hand-weaving techniques.
PLATE V

TABLE MAT: Made from fibre using a hand needle.

PLATE VI

TABLE MAT: Made from the yarn and fibre using hand-weaving techniques.
TABLE MATS: Made using comb hedle-weaving technique.
PLATE IX

LOOSE COVER: Made using a crochet needle.

PLATE X

PLACE MAT: Made using a crochet needle.
PLATE XI

WALL HANGING: Made using knitting needles.

PLATE XII

All the Articles Put Together
General discussions.

The method of extraction used in this study was found to have good results inspite of being rather slow and tedious. The percentage yield of 1.7% was quite low. However this was not significantly different from that of 2-3% reported by Purseglove (1972).

The pineapple fibre was found to be a staple fibre ranging in length between 20 and 70cm. A graph of length versus number of fibres showed the length distribution to be consistent with the shape of leaf profile as shown in figure 7. The length findings of pineapple fibres in this study exceeded those reported in other findings as indicated in literature review. This could be explained by the stage of plant growth at which the fibres were extracted. As reported by Purseglove (1972), fibres in other findings have been extracted at an early age, often before the plant is 18 months old. In such a case, the leaves may not have grown to full length hence the shorter length of fibres. In this study the fibres were extracted at the stage of final harvest of the plant crop, in which case the leaves may have developed to full length, yielding longer fibres.
The longitudinal section of the fibre showed cross markings and striations along the length of section under observation while the cross-sectional view showed polygonal shapes. The actual cross-sectional shape was seen as a crescent shaped outline.

The pineapple fibre burns readily and quickly emitting the smell of burning paper, and leaves a small amount of greyish ash. On exposure to dry heat, the fibres did not melt but charred at a temperature below 337 °C. This could be taken as an indication that the fibre can withstand normal exposure to heat that may be experienced during processing and care of the fibre.

The moisture regain of 10.39%, which was similar to that reported by the Philippines Textile Research Institute (PTRI) of 10.53% is fairly relatively high. This is a desirable characteristic in a textile fibre as it contributes to comfort properties in fabrics made from the fibre. It is also an indication that the fibre can be dyed easily. The pineapple leaf has a mean breaking tenacity of 2.35 g/denier. According to Hall (1969) the textile industries require that a fibre should have a minimum of 1 g/denier for it to be of use. This implies therefore that the pineapple leaf fibre meets the
requirements for industrial use as a textile fibre. It is important to note however that the fibre was found to be weaker when wet. There was a decrease in strength of about 25% in the wet fibres. This behaviour is contrary to that of other natural cellulosic fibres such as cotton, flax and ramie whose strength increases when wet. However this finding is partly supported by Cobley (1970), who says that the pineapple fibre is destroyed by water. The decrease in wet strength would imply that the fibre would require careful handling when wet. The pineapple fibre has a low elongation of 1.80%. It was also noticed that this elongation increased by about 8.24% to 1.97% when the fibres were wet.

An attempt was made to spin the fibres using the spinning wheel, as it had been proposed. However this was found to have unsatisfactory results as the yarn produced had weak joints, that could be easily pulled off. The hand spinning technique used produced strong two ply yarns of various desired thicknesses. However this method of spinning was rather slow and tedious. The yarns obtained were found to be quite pliable flexible and soft to work with, and this made it possible for such techniques as hand knitting and
crocheting to be used in the making of various articles.

To enable further conclusions to be made on the characteristics and hence the quality of the pineapple fibre, the findings of this study were compared with similar characteristics of other natural cellulosic fibres where such information was available, as discussed below.

The longitudinal section of pineapple leaf fibre compares with that of flax where cross markings and striations also appear, (Joseph 1976). The crescent shaped outline seen in the cross-section and the polygonal shapes is similar to that of the transverse section of mauritius fibre and also sisal (Textile Institute 1970).

Natural cellulosic fibres burn rapidly and emits the smell of burning paper, leaving a small amount of soft grey ash (Tylor 1972). The burning characteristics of the pineapple leaf fibre are similar to those of other natural cellulosic fibres. Sisal and other leaf fibres, when subjected to theBillinghames test assume a pale yellow colour, while abaca assumes an orange colour. In this study pineapple leaf fibres were found to behave like sisal and other leaf fibres. In the drying twist
test, flax, and ramie twist in a clockwise direction, hemp twists in an anticlockwise direction, while cotton twists alternately in opposite directions. The pineapple leaf fibre behaved like hemp. The microscopical examination of the ash of particles of sisal, hemp, jute and abaca, as indicated by Textile Institute (1970) are as shown below.

Sisal - rod like structures \|
Hemp - cluster crystals :: ::
Jute - solitary crystals [ ]
Abaca - stegmata [ ] [ ] [ ] [ ]

The pineapple leaf fibre showed rod like crystals, similar to those of sisal (see plate x).

The maximum length of various natural cellulosic fibres are shown below (in cm).

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sisal</td>
<td>130.0</td>
</tr>
<tr>
<td>cotton</td>
<td>6.0</td>
</tr>
<tr>
<td>Flax</td>
<td>56</td>
</tr>
<tr>
<td>ramie</td>
<td>over 46</td>
</tr>
<tr>
<td>pineapple</td>
<td>70</td>
</tr>
</tbody>
</table>

(Lock 1962 and Joseph 1976)

The length of the pineapple fibre therefore compares well with other 'long' staple fibres. The moisture regain
of pineapple fibre is similar to other natural cellulosic fibres as the figures below show.

<table>
<thead>
<tr>
<th>fibre</th>
<th>% moisture regain (standard)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cotton</td>
<td>7-12</td>
</tr>
<tr>
<td>flax</td>
<td>12</td>
</tr>
<tr>
<td>sisal</td>
<td>12-13</td>
</tr>
<tr>
<td>hemp</td>
<td>12</td>
</tr>
<tr>
<td>jute</td>
<td>13.7</td>
</tr>
<tr>
<td>ramie</td>
<td>6.0</td>
</tr>
<tr>
<td>pineapple</td>
<td>10.39</td>
</tr>
</tbody>
</table>

Sources: (Lock 1962, Joseph 1976 and Hollen 1988).

The breaking tenacity range of 1.7 - 3.0 g/d is much lower than that of natural cellulosic fibres as shown below.

<table>
<thead>
<tr>
<th>fibre</th>
<th>range (g/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>3.0 - 5.0</td>
</tr>
<tr>
<td>flax</td>
<td>5.5 - 6.5</td>
</tr>
<tr>
<td>regular rayon</td>
<td>0.2 - 2.6</td>
</tr>
<tr>
<td>hemp</td>
<td>5.8 - 6.8</td>
</tr>
<tr>
<td>jute</td>
<td>3.0 - 5.8</td>
</tr>
<tr>
<td>ramie</td>
<td>5.3 - 67.4</td>
</tr>
</tbody>
</table>

Sources: (Joseph 1976, Tortora 65)
From the figures above the pineapple fibre is weaker than other natural cellulosic fibres but it is slightly stronger than regular rayon. Tortora (1978) also indicates that cotton is 10 to 20 percent stronger when wet than dry, while flax is about 20 percent stronger when wet. The findings for wet tenacity of the pineapple leaf fibres indicate a 25% decrease in tenacity. This characteristic is similar to that of regular rayon, which loses about 50 percent of its strength when wet. In terms of strength therefore, the pineapple leaf fibre can only be compared to regular cellulose fibre.

The elongation at break value of 1.80% is close to that of flax of 2.0%. According to Hollen (1988), the elongation at break for cotton, flax, and regular rayon increases when the fibres are wet. The 8.24% increase of elongation of wet pineapple fibres is similar to that of the fibres mentioned above.
This study was carried out to investigate the possibility of extraction of fibres from the leaves of the smooth cayenne which is the main pineapple variety grown in Kenya, and to further analyze the quality of the fibre in relation to other cellulosic fibres that are already in use in the textile industry. The general aim was to find out whether there could be a possibility of utilizing the fibre, given that vast quantities of pineapple leaves go into waste every year.

The specific objectives of the study, together with a summary of the procedures and findings for each objective are given below. Where applicable, methodological limitations that occurred are also mentioned.

Objectives (1) To extract fibres from pineapple leaves using hand methods: The fibres were extracted using hand decorticating methods which involved scraping off the leaf matter with blunt knives. A total of about 65kg of fresh leaves was used and this produced about 1.1kg of long white fibres. The main disadvantage of this method
was that it was slow and tedious, and many of the fibres were cut off and wasted.

(2) To identify physical properties of the fibre, and to compare these properties with similar and already established properties of other cellulosic fibres: A number of fibre physical properties were tested using the appropriate textile testing procedures and equipment. The properties tested were microscopic appearance, burning tests, microscopic examination of fibre ash, moisture content and regain, wet and dry breaking tenacity, wet and dry elongation at break, and the drying twist test. The fibre was found to have microscopic and burning properties that are characteristic of other natural cellulosic fibres. The length of the fibre ranged between 20 and 70 cm, and a moisture regain value of 10.39%. The fibre strength, which was found to decrease in wet fibres, was about 2.35 g/d for the dry fibres and 1.8 g/d for the wet fibres. The elongation at break on the other hand was found to increase in the wet fibres, with the value for dry fibres being 1.80% and that for wet fibres being 1.97%.

On comparison with other cellulosic fibres the pineapple leaf fibres were found to have characteristic
that were similar to those of other cellulosic fibres. The pineapple fibres were longer than flax and ramie, but moisture regain value is comparable with that of cotton. The findings on the strength of the fibre also showed it to be generally weaker than other natural cellulosic fibres such as cotton, jute, hemp, flax and ramie. It's strength characteristics including the decrease in strength when wet are similar to those of regular rayon which is a regenerated cellulose fibre.

(3) To make yarn from the fibres using hand spinning methods: Two ply yarns of different thicknesses were made using hand spinning methods. The yarns obtained were strong, soft and pliable. Spinning with a spinning wheel was found to have unsatisfactory results, as the yarns produced had weak joints that could be pulled off easily.

(4) To identify some possible uses of the yarn using hand looms and other hand weaving techniques: A variety of hand techniques were used to make a number of textile articles. Crocheting was used to make a school bag and a chair cover, hand knitting was used to make a wall hanging, needle work techniques were used to make table mats, a comb heddle was used to weave a mat, and a
hand weaving technique used to make a shopping bag (kiondo). Due to the limited amount of yarn obtained, the use of hand looms was not employed.

In conclusion therefore, the pineapple leaf fibre can be extracted using hand decortication methods to liberate long white fibres whose characteristics are similar to those of other cellulosic fibres. The fibres can also be used to make a variety of textile articles using a variety of hand techniques.

Recommendation for Further Research

As mentioned in the introductory chapter, part of the significance of this study was to facilitate further research, in order to explore the possibility of making full use of the pineapple fibre as in other countries. Based on the findings of this study therefore, the following have been made as recommendations for further research. This could be mainly directed to textile industry in Kenya and to the local users of hard fibres such as the "Jua Kali" makers of sisal articles.

1. The methods of extraction used in this study was found to be slow and tedious and therefore unsuitable for large scale production of the fibre. There is need for further investigation into faster methods of
extracting the fibre.

2. There is also need for investigation of faster and more effective methods of spinning the fibre.

3. Since this study has established that the pineapple fibre qualifies for use as a textile fibre, further research is important, to find out whether such a project if undertaken would be economically viable.

4. Given that the decrease in wet tenacity of the fibres as found in this study is not characteristic of other cellulosic fibres further research is recommended in order to verify this finding.
REFERENCES


