"Kapok Fibre: A Perspective Fibre"

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Abstract

Kapok is a natural cellulosic fibre found in selective regions of the world that was once used for technical application rather than apparel purpose. They have limited use to market and have faded away due to the upper hand of the manmade fibres like polyester, polypropylene and other substituting fibres. In this paper, information regarding the fibres in various sectors like harvesting areas, structure of fibre with the chemical composition of material, the various properties that would makes the fibre suitable for end use and the advantages along with limitations where researchers and technicians have to work on for making this natural environmental fibre back to track.

Keywords: Acoustic insulation, natural cellulosic fibre, oil absorbent, vegetable fibre

1. Introduction

Kapok fibre is soft silky cellulosic fibre but different from other cellulosic fibre. They have significantly homogeneous hollow tube shape. The chemical composition of kapok fibre were studied and two different results were obtained one result stated 64% cellulose, 13% lignin and 23% pentose (by Kobayshi et al 1977) the other result stated that it is composed of cellulose (35 % dry fibre), xylan (22%), and lignin (21.5%) by Hori et al [2]. Due to the presence of large amount of lignin and wax content and bitterness, they are inherently mold free and free from pesticides.

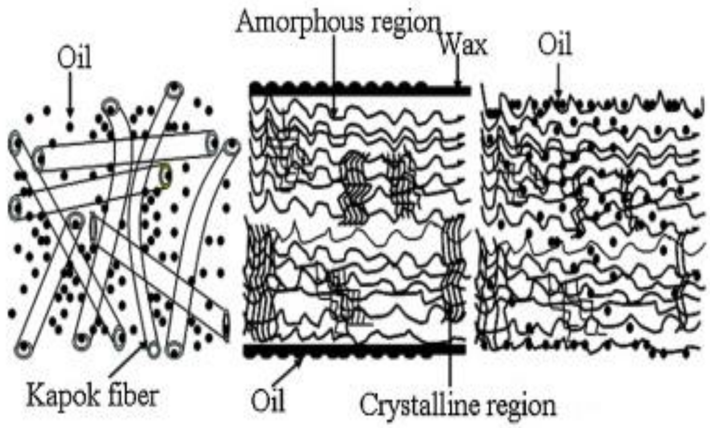

Fig 1.1 Fig 1.2

In figure 1.1 and 1.2 the nature of kapok fibre is shown. Kapok is a fibre extracted from the seedpod of the kapok tree. The tree is grown chiefly in mainland Asia and in Indonesia. Sometimes called silk cotton or Java cotton, the kapok can grow up to 4 meters (13 feet) per year, eventually reaching a height of 50 meters (164 feet). Individual fibres are 0.8 to 3.2 cm (0.3 to 1.25 inches) long, averaging 1.8 cm (0.7 inch), with diameters of 30 to 36 micrometers (a micrometer is about 0.00004 inch) and has a density of 0.29g/cm3 [1].

2. Structure of kapok fibre

Kapok fibre wall is different from that of cotton fibres both in the lateral and the longitudinal sections of the fibre. The cell wall is divided into five basic walls or layers: an outer skin S, a primary wall W1, secondary wall W2, tertiary wall W3 and an inner skin IS. IS is thin (40–70 nm) and acts as a protective layer for the fibre. W1 is thicker than S, but thinner than both W2 and W3 its thickness varies from 160 to 240 nm, with an average of about 200 nm. The thickness of W2 is about 500 nm, which is similar to that of W3. The inner skin IS is very thin and uneven in thickness, with an average thickness of about 40 nm that could be distinguished easily in the cross-sections. Additionally, there were transition layers L1 and L2, observable between W1 and W2 and between W2 and W3 respectively.

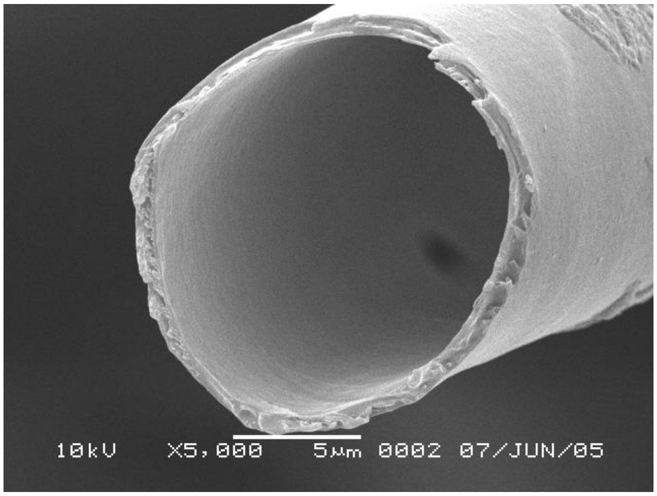

Fig 2.1

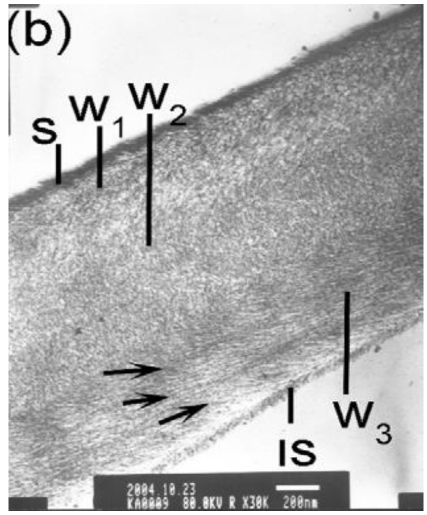

Fig 2.2

The fig 2.1 and 2.2 shows SEM and TEM images of kapok fibre respectively.

Kapok fibres are characterized of having high levels of acetyl groups (13.0%). Usually cell walls of plants contain about 1%–2% of acetyl groups attached to non-cellulosic polysaccharides. Kapok fibre are significantly super hydrophobic and do not get wet with water [2].

(a) SEM images of kapok

The SEM images of kapok fibre shows homogenous circular cross section with wide air filled lumen having wall thickness of about 1-2µm. the homogenous hollow wall thickness ranged from 0.8 to 1.0µm making water difficult to penetrate. The average area occupied by lumen contributes around 64% which does not collapse after harsh mechanical action. Kapok fibre requires low energy for production as they have low trash and foreign contaminant and hand opening & hand cleaning is sufficient enough [3] .

(b) FTIR of kapok

The infra red spectra of kapok showed intense broad band 3364.96 cm^{-1} corresponding to OH strong stretch, this is due to intermolecular hydrogen bonding. Similarly band 2917.46 cm^{-1} corresponding to C-H strong stretch and peak at 1739.87 corresponding to C-O double bond strong stretch was revealed. Peak at 1374.34 was due to C-H bending due to bonded acetyl group and similar peaks at 1244 and 1057 corresponded to O-H and C-H due to weak bonding and weak stretching respectively [4].

(c) Cellulose:

Cellulose is the most abundant organic polymer on Earth, which is an organic compound with the formula $(C_6H_{10}O_5)n$, it is a polysaccharide consisting of a linear chain of several hundred to over ten thousand β(1→4) linked D-glucose units the degree of polymerization varies between 200 to 10000 but it generally lies around 3000 degree of polymerization depends on method of isolation and purification. Hemicellulose is the generic term of polysaccharides that is in vegetable fibre other than cellulose, the degree of polymerization of hemicelluloses ranges around 100. Cellulose is an important structural component of the primary cell wall of green plants. Cellulose is used to make water-soluble adhesives and binders such as methyl cellulose and carboxymethyl cellulose which are used in wallpaper paste, The presence of lesser amount of hydroxyl group in kapok (cellulose content) makes the fibre hydrophobic.

(d) Lignin:

Lignin or lignen is a complex chemical compound most commonly derived from wood, and an integral part of the secondary cell walls of plants ($C_9H_{10}O_2$, $C_{10}H_{12}O_3$, $C_{11}H_{14}O_4$). Lignin plays a crucial part in conducting water in plant stems. The polysaccharide components of plant cell walls are highly hydrophilic and thus are permeable to water, whereas lignin is more hydrophobic. The crosslinking of polysaccharides by lignin creates an obstacle for water absorption to the cell wall.

(e) **Xylan**:

Xylans are polysaccharides made from units of xylose (a pentose sugar). Xylans are almost as ubiquitous as cellulose in plant cell walls and contain predominantly β-D-xylose units linked as in cellulose. Xylan is found in the cell walls of some green algae, especially macrophytic siphonous genera, where it replaces cellulose. Similarly, it replaces the inner fibrillar cell-wall layer of cellulose in some red algae

The chemical parameters of various vegetable fibres are depicted in table No 1

Table 2.1: Chemical Composition of vegetable fibres.

S.no	Fibre	Cellulose %	Hemi-cellulose %	Pectin %	Lignin %	Extractives %	Moisture %
1	Cotton	94.0	2.0	2.0	-	2.0	8.0
2	Kapok	35-65	23.0	23.0	13.0	-	0.0
3	Flax	71.2	18.5	2.0	2.2	6.0	9.0
4	Hemp	74.3	17.9	0.9	3.7	31	8.76
5	Ramie	76.2	14.5	2.1	0.7	6.4	-
6	Jute	71.5	13.3	0.2	13.1	1.8	9.93
7	Sisal	73.2	13.3	0.9	11.0	1.6	6.2
8	Pineapple	69.5-71.5	-	1.0-2.0	4.4-4.7	5.2	6.1
9	Murva	70.09	-	-	12.86	-	9.1
10	Furcraea	80.00	-	-	18.0	2.0	7.6

Physical characteristics of various natural fibres are shown in table No 2

Table 2.2: Physical parameters of natural fibers'

S.no	Fiber	Fineness Denier	Tenacity g/den	Relative weight	Elongation at break	Fibre color range
1	Cotton	2.0	2.5	200	8.0	Cream white
2	Kapok	0.4-0.7	1.4-1.74	-	1.8-4.23	Ivory white to camel brown
3	Jute	20	3	167	1.5	Creamy white to grey brown
4	Flax	5	5	100	1.5	Bleached white to grayish brown

5	Hemp	6	4	125	2.0	Light brown to grayish brown
6	Ramie	5	5	100	4.0	Bleached white to grayish brown
7	Sisal	290	4	125	3.0	Creamy white to yellowish brown
8	Pineapple	27	41.4	-	2.4	-
9	Murva	60	5.8	-	1.4	-
10	Abaca	190	5	100	3.0	Creamy white to dark brown
11	Henequen	370	3	167	5.0	Creamy white to yellowish brown
12	Istle	360	2.5	200	5.0	Nearly white to light reddish yellow

3.1 Properties of kapok fibre

(a) Absorbency of kapok

The absorbency of the material is based on two factors the surface tension and the surface energy of the materials. The lesser amount of cellulosic content (hydroxyl group) present on the wall of kapok makes it hydrophobic. Water has a high surface tension (72 dynes/cm) and Oil has a surface tension of 30–35 dynes/cm. The absorption takes place with nullification of the surface tension by surface energy of the material but the very low surface energy of kapok fibre makes it hydrophilic and the presence of waxy hollow structure makes it oil absorbent. The Sorption capacities of the packed kapok assemblies are very much dependent on their packing densities [6]. With better packing densities the sorption levels increase and decreases vise versa. The properties like cohesion and capillary action plays an important role in absorbing and retaining of fluid, adhesion refers to attraction of one material to another. The retaintivity value of the material is very high losing nearly 8 to 12 percent of the absorbed oil based compounds after 1 hour of dripping. On repeated usage at fourth cycle the retentivity decrease to only 27- 30% of the parental value at packing density of 0.02 g $cm^{-3.}$ The oil recovery rate increases with increase in thickness of the oil layer in feed stream [7].

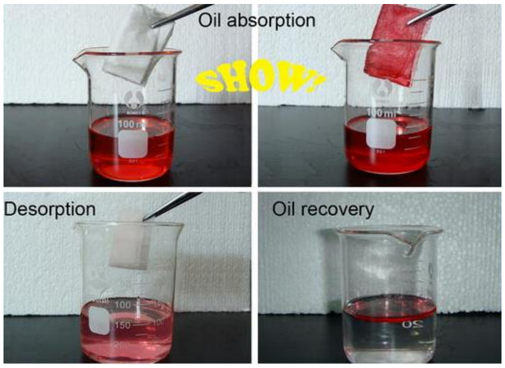

Table 3.1.1: Absorbancy of Kapok fiber

When oil thickness exceeds 60 mm, a constant flux of 3.8–5.0 L/(m^2 min) can be achieved by the kapok wall of 55-, 75- and 95-mm thick respectively under the natural pressure gradient. The hydrophobic/oleophilic characteristics of the kapok fibre could be attributed to its waxy surface while its large percent of lumen contributed to its excellent oil absorbency and retention capacity [1].

(b) Sound absorption

Kapok fibres have very good acoustic damping property due to its natural hollow structure. The sound absorption is directly affected with bulkiness of the fabric, thickness and arrangement of fibres but less dependent on fibre length [8].

(c) Compressibility of the kapok fibre

The compressive nature of the fibre is not great even on having hollow structure because of high crystallinity. They are brittle and tend to break out. The fibre gets backs to the original position literally but 90% fibres in the wet-treated assemblies (unpressured) remained circular shapes (c/s wise), but more than 80% of fibres in the wet-pressure-treated assemblies seemed apparently crushed (c/s). The loss of interspaces among fibres and the hollow structure of kapok fibre in the dry pressure- treated assemblies is much less than that of the wet-pressure-treated samples. The pressure treatment greatly affects the hollow status of kapok fibres [9].

3.1.2: Kapok fabric for upholstery purpose

(d) Thermal behavior of kapok fibre

Heat is transferred by means of conduction convection and radiation. Of these, conductivity is the most important mechanism of heat transfer. The heat insulating performance of wadding is usually represented by the combination of conductivity and heat convection. The conductivity coefficient (W/m°C) of immobile or trapped air can be regarded as a major contributor to the thermal property. The properties and the structural configuration of the fibrous materials play a very important role in thermal behavior. The heat retention of kapok was better than that of other fibres due to the static immobile air held in the large lumen region of kapok. The kapok's conductivity dregs between 0.03 and 0.04 W/m.ºK for density which varies between 5 and 40 kg/m3. Taking also into account year average diffusivity of 17.1x10G7 m2/s, kapok has good heat insulator. [10].

(e) Spinnability

Kapok fibre because of its short length of low intensity of cohesive property difference and lacking of elasticity so that it is difficult to solely spinning these deficiencies limits the textile clothing in the aspect of application and development. Using kapok fibre and other fibre, product with super high heat preservation, strong and fast moisture conductivity can be achieved.

(f) Weavability

The Weavability of kapok fibre is not possible because of very smooth surface of the fibre this leads to less cohesive force creating a slippage between the fibres, surface roughening has to be done by removal of waxy particle by means of plasma treatment or use of chemicals, it can also be done by blending of kapok fibre with other cellulosic materials like cotton, hemp, flax, jute or other material.

(g) Dyeability of kapok fibre

The material being hydrophobic in nature does not allow water based dye molecules to color the fibre and the wax on its surface is also a hindrance to dyeing. The surface has to be modified to makes it dyeable. The anionic dye such as reactive active dye is used to overcome the low rate dyeing performance.

Dyeing of kapok comprises the following steps: pre-treating kapok textile so as to remove some waxy substances, impurities and the like on the surface of the kapok fibre and achieve certain whiteness; and then adding a complexion rare earth mordant into a dye bath of the pretreated kapok textile, and mordant dyeing the kapok textile. Rare earth elements ions and the dye of fibre and other compounds of the hydroxyl group azo group or sulfonic acid group and so on to form the compound of the rare earth are used for printing and dyeing because of the rare earth element the fibre and the impurity on the complex containing the element crack impurity form the complex compound after washing. They are then dispersed into the solution to improve the capillary effect [11].

3.2 Applications of Kapok fibres

Kapok is considered unsuitable for textile purposes, because the fibre is brittle, smooth and slippery. They are used in bedding, upholstery industries, in the production of life-saving equipment and in the construction of thermally insulated and soundproof covers and walls. On account of its buoyancy, freedom from water-logging and weight-bearing capacity, it is the material par excellence for the manufacture of lifebuoys and belts, waistcoats and other naval life-saving appliances [12].

- Oil absorbent-Kapok fibres have very good oil absorbency, this property making it the best natural material for separation of oil based products from water in case of oil spills in sea with best durability and retentivity of oil material .
- Buoyancy suit/anti drown suit-The hollow structures have air immobilized within them making it a good buoyant material which is used for making anti drowning suits.

- Filter media- These air filled structures air the basic design for filter medium making them good filter objects for oil and air filtration.
- The hollow fibre has air inside allowing combustion deep inside the material. Flame travel quickly within the material which makes it unsuitable for apparel wears.

Kapok apparels

a. Kapok Jersey Fabric- Jersy knit - suitable under layer, thin, breathable and comfortable.

b. Kapok Double Fabric-Double knit - thick, warm mid layer, yet still breathable.

c. Kapok Oxford Fabric Oxford weaves - a paradigm specialty, thin and dense, suitable casual shirting fabric, or outerwear. - This weave keeps you warm while wet or dry.

The natural bitter constituents of the Kapok fibre are anti-bacterial and anti-microbial therefore Moths, mites and other microorganisms cannot infest the material.

3.3 Advantages of kapok fibre

- The hollow structure makes the material light weight and has 8 times the density lower than cotton.
- The waxy surface makes it hydrophobic and the air entrapped into the fibre makes it to have good buoyancy effect.
- The resiliency effect of the fibre is also high due to hollowness which helps it to retain its shape even after cyclic loading.
- Having waxier surface it has non soiling property by nature.
- Cushioning materials made from kapok give much higher comfort level due to its flexible nature and can retain their shape after use.
- Having air entrapped inside this acts as good thermal insulating material and good acoustic insulator.
- Since kapok fibres are covered with a thin film of wax they prevent the growth of insects and tiny organisms, it is not necessary to spray the trees with chemicals or pesticides and does not get affected on long storage of end product.
- Being a natural material they have no environmental flaws.

- Ceiba pentandra bark decoction has been used as a diuretic, aphrodisiac, and to treat headache, as well as type II diabetes[13]

3.4 Limitations of Kapok fibre

- The fibres are fragile and break easily; therefore they are not suitable for weaving or spinning to textile fabric Being waxier on surface the slipperiness makes it difficult to weave.
- The fibres are very fine and are airborne in minutes; this property makes it irritant to lungs and needs extra care during work.
- The air entrapment in the fibre makes it support combustion and the wax content on the surface helps it be much more inflammable.

3.5 Prospects of kapok

The market of kapok fibre usage has seen downfall in the recent 30 years time due to the various features of polyester material which gives a better competition in all aspects. But developments in technology have overcome the drawbacks to certain limits by making it spinnable along with cotton in 2:3 ratios. Furthermore advancement is expected to tack this in a better usage.

4. Conclusions

Considering the environmental pollution as a major drawback of manmade material the need for natural material to replace the existing synthetically manufactured materials is at a high preference and one such fibre is kapok fibre which has been let down by user due to its failure as apparel product and some relative chemical behavior..

The chemical behavior of fibre has been studied to analyze the hydrophobic/oleophilic behavior, thermal behavior, acoustic insulation and various other parameters to support its enduse. The advantages and its limitation along with future forecast based on research work that have been carried out to bring back the material to better use.

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