

## - Case Study -

# Dole Sunshine Company turns banana waste into fibers of purpose with Musa Fabric: Natural fiber from banana pseudo-stem



### Sustainable development goals (SDGs)

- Goal 8: Decent work and economic growth
- Goal 11: Sustainable cities and communities
- Goal 12: Responsible consumption and production



### Relevant concept/ issues

Waste management



### Relevant sector

Agricultural sector

## Background

The demand for fiber as a raw material to make various products is increasing. Fiber can be extracted from the seed, leaves, fruits and stem of a plant. Banana is one of the main fruits grown in the Philippines; it provides food and is a source of industrial raw materials. Aside from the fruit, banana blossom and its trunk pith can be eaten, and natural fiber can be extracted from the trunk (pseudo-stem) that is usually discarded as waste after the harvest.

The use of natural fibers to produce clothes, carpets and other handicraft products has grown tremendously. Various plants are used as a source material for fiber to meet consumer demand. In the Philippines, natural sources of fiber are coconut, water hyacinth, pineapple, and abaca. A lot of attention has been given to these plants.

However, banana (*Musa sapientum*), which resembles, and is closely related to abaca (*Musa textilis*), is also a good source of fiber. The Philippines is one of the largest growers of bananas in the world. In addition, banana is the fourth largest commodity produced in the Philippines next to paddy rice, coconuts and native pig meat. Due to the high volume of bananas that are harvested in the country, there are a lot of remaining banana stems that can be used to produce banana fiber and help local banana farmers with their livelihood.

## What is a pseudo-stem?

Pseudo-stem (see Fig. 1) is an abundant residue of the banana bunch harvest, and is a source of water, nutrients and organic substances.

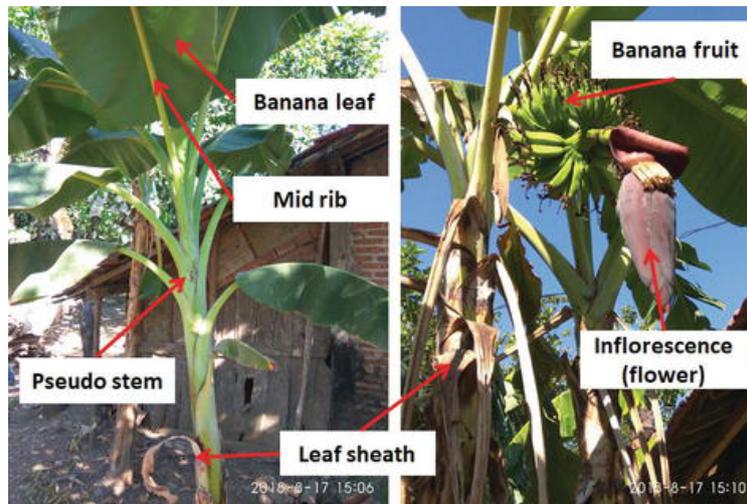


Fig. 1. Parts of a banana tree.  
Source: <https://www.intechopen.com/chapters/64570>

The banana plant (*Musa spp.*) and plantains belong to the *Musaceae* family and are widely grown worldwide. They are tropical herbaceous plants with the appearance of trees with fibrous trunks. However these are false stems, and are referred to as pseudo-stems (Akpabio et al. 2012). They are composed of concentric layers of leaf sheaths (Ho et al., 2012). Bananas are the second most important crop after citrus, and account for 16% of world fruit production, with 120 million tons derived from an area of over 8 million ha and which is grown in over 112 countries (see Fig. 2) under tropical and subtropical conditions (FAO, 2019).

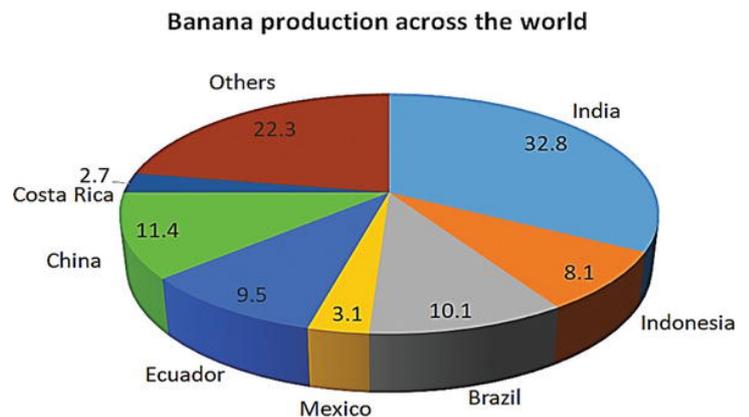


Fig. 2. Banana production across the world in 2010.  
Source: Ray et al., 2013.

The pseudo-stem fiber of the banana plant resembles the pineapple leaf, sisal, and other hard fibers, however the pseudo-stem fiber is a little more elastic. The major uses of banana pseudo-stem fiber are in making specialized and high-quality sanitary products such as baby diapers, textiles, and for paper used in banknotes. The banana pseudo-stem fiber can also be used for marine rope as the fiber has good resistance to seawater and has buoyancy properties. Other uses of this fiber are for making coffee and tea bags, filter cloths, reinforcement fibers for plaster, disposable fabrics, and light-density woven fabrics.



Fig. 3. Banana fiber paper.  
Source: <https://materialdistrict.com/material/banana-fibre-paper/>



Fig. 4. Banana fiber textiles.  
Source: <https://textilevaluechain.in/in-depth-analysis/banana-fibre-2/>

## Why are banana pseudo-stems used to make fiber?

Each banana tree produces just a single bunch of fruit (Ho et al., 2012). Following harvesting in banana plantations, the pseudo-stem is cut at about 70 cm in height, and so several tons of agricultural residues are produced every day (Nkengafac et al., 2019), and which Ingale et al. (2014) calculate to be about 220 tonnes per hectare per year. The felled pseudo-stem is usually left next to the cutting place and can become organic waste and cause environmental pollution (Li et al., 2010). In Brazil, pseudo-stem waste is kept in the soil to efficiently retain the nutrients in the plantations and to prevent negative environmental impacts.

In addition, for every ton of bananas harvested, about 100kg is rejected (for example, rotten fruit) and approximately 4 tons of biomass waste (e.g., leaf, pseudo-stem, rotten fruit, peel, fruit-bunch-stem, rhizome, etc.) are produced. This means that for every cycle of banana production, four times more biomass waste is produced than the bananas themselves. Based on other research, it has been estimated that one hectare of a banana farm can produce approximately 220 tons of biomass waste.

Farmers usually dispose of this waste into lakes and rivers or burn it. If not properly managed, banana tree waste can cause problems for the environment, because if they are dumped in wet conditions or burned they produce greenhouse gas, which can cause additional problems. It is believed that this crop waste can be used in a useful way, namely, as a source of cellulose fiber with further applications.

In recent years, people have focused on forest preservation and finding ways to use agricultural and forest residues. This trend is caused by a rapid increase in the consumption of wood fiber-based products. However, the demand for wood fiber may result in illegal logging activity due to the decreasing number of permitted wood harvesting resources. In addition, the use of cellulose fiber from the forest and agricultural residues has many advantages; it is environmentally friendly, recyclable, low cost and even free.

## Production of banana pseudo-stem fiber

### 1. Process 1: Extraction of fiber

Fibers from the banana pseudo-stem leaves can be extracted with a decorticator machine. The machine is used to strip bark, skin, wood, stalk, and grain. The extraction process is conducted as soon as the pseudo-stem's leaves have been cut. A common method in practice is to use a combination of water retting and scraping. The first step, called tuxing, involves separating the fiber bundles from the remaining parts (see Figures 3 and 4).

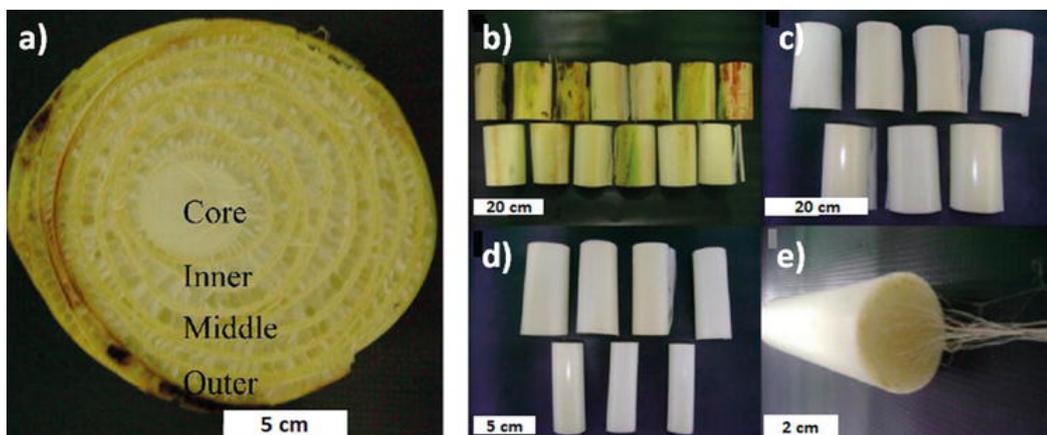


Fig. 5. Banana pseudo-stem trunk cross section and its parts: (b) outer parts; (c) middle parts; (d) inner parts; and (e) core parts. Source: Pereira et al., 2014.

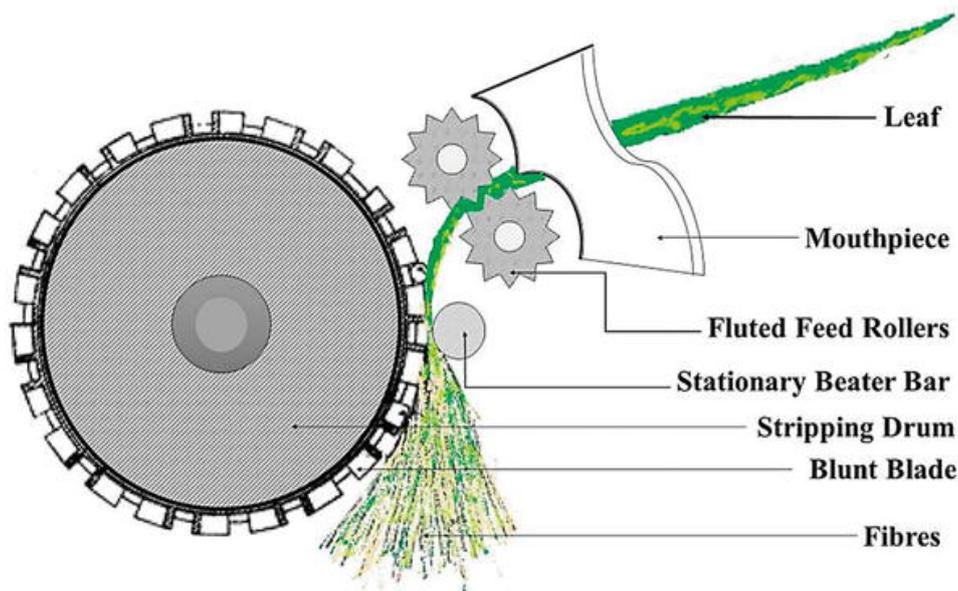


Fig. 6. Pseudo-stem fiber extraction machine.  
Source: <https://www.intechopen.com/chapters/64570>

## 2. Process 2: Retting of banana pseudo-stem fiber

Retting of banana fiber involves separating the fiber bundles from the cortex or wood and the cementing material (such as lignin and hemicellulose) between the fibers in the bundles. This loosening of the fiber bundles occurs in two stages: 1) the physical stage through water absorption and then removal of the soluble substances and 2) the microbial stage, either aerobic or anaerobic when fungi or bacteria used. As a result, various cementing tissue components are removed. Retting is carried out to increase the mechanical properties of natural fiber, such the banana pseudo-stem.

## Banana pseudo-stem fiber properties

### 1. Morphological properties

An optical microscopy examination of the pseudo-stem fiber from a banana plant revealed that it is a multicellular fiber, like other vegetable fibers (see Fig. 7). Its hollow structure suggests that the fiber will possess good insulation and absorption properties. Treating the fiber with either alkalines or acids may result in good quality fibers.

### 2. Physical and mechanical properties

Banana pseudo-stem fibers have physical and chemical characteristics and other properties that make them good quality fiber. Li et al (2010) reported **that the banana pseudo-stem fiber has good elasticity, tensile strength, and stiffness**, which makes it a promising fiber material.

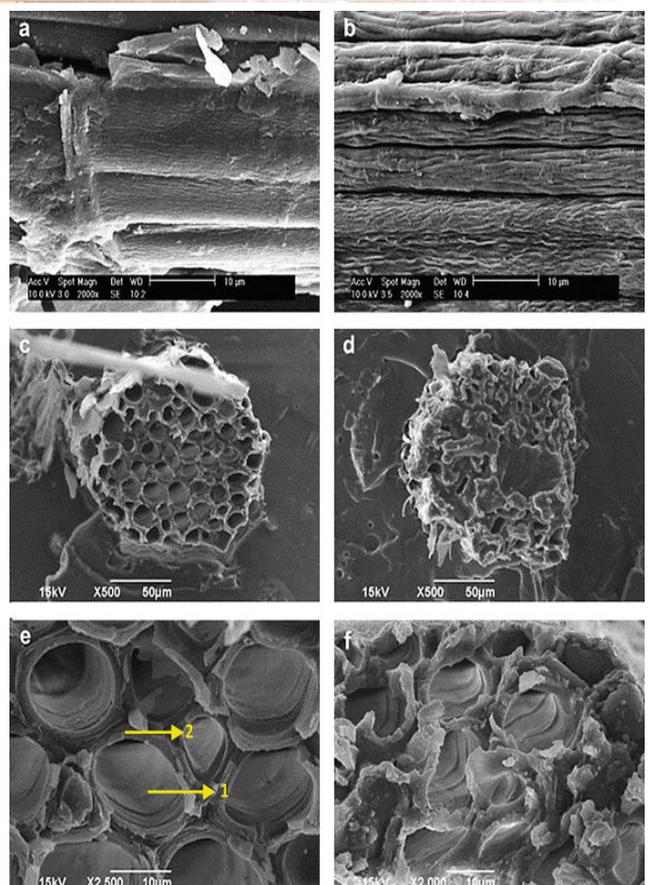


Fig. 7. Microscopic images of banana pseudo-stem fiber.  
Source: <https://www.intechopen.com/chapters/64570>

### 3. Durability and biodegradability

Studies on the durability of banana pseudo-stem fiber have been carried out at the Center of Study for Natural Fiber and Natural Dyes (CSNFD) at the Department of Chemical Engineering, Concentration Textile Engineering, Universitas Islam Indonesia (UII). The studies showed that the durability of banana pseudo-stem fiber can be retained up to three months in storage. However, if the storage period of the fiber is extended beyond 3 months, the strength of the fiber decreases considerably. Furthermore, **because banana pseudo-stem fibers are biodegradable, they can be categorized as environmentally friendly.**

### 4. Thermal properties

Thermogravimetric analysis (TGA) has been carried out to analyze the heat stability or thermal degradation of banana pseudo-stem fiber. Thermal conductivity of banana pseudo-stem fiber is found to be quite low, at 0.0253 W/m<sup>2</sup> K, which suggests that these fibers could be used as **effective thermal insulation.**

### 5. Antibacterial test

Banana and banana pseudo-stem contain pathogenesis proteins, which contain **antimicrobial properties.** The higher the moisture regain of a natural fiber (the level of moisture absorption), the lower the bacteriostatic rate. The hygroscopicity of the banana pseudo-stem fiber is the highest among the others, whereas the ramie fiber has the lowest moisture regain.

---

## The application of banana pseudo-stem fiber

### 1. Local example from the Philippines: The Dole-Musa collaboration

**Dole Sunshine Company (DSC)** (<https://dolesunshine.com/us/en/>) has partnered with social enterprise, **Musa Fabric**, to turn banana waste into fibers of purpose. The partnership creates textiles, woven by inmates.

**Musa** (<https://musafabric.linker.store/>) is the first fabric in the province to be made of banana and abaca fiber, which is woven and tailored by the Persons Deprived of Liberty (PDL) in jails /Women Community/Persons With Disability (PWD) and IPS/Lumad/Muslims in Davao del Norte, Philippines. Musa Fabric was showcased during the New York Fashion Week in February 2022. There is more information about Musa Fiber at the New York Fashion Week here: <https://www.youtube.com/watch?v=J4X34uDreDY>

Consumers around the world are becoming more conscious about their choices and have begun to demand planet-friendly and people-friendly fashion options. The Dole-Musa collaboration achieves a more circular and sustainable process with the banana fiber - the fiber of purpose – for the maker, the consumer and the ultimate producer: our planet. Stopping 4.4 million pieces (200,000 metric tonnes) of banana pseudo-stem waste from reaching landfills, can reduce approximately 258,720 tonnes of carbon dioxide equivalent (CO<sub>2</sub>e) emissions, and instead create fashion products worth over US\$50m, thereby benefiting the livelihoods of more than a hundred people.

This partnership delivers three Dole promises:

- a. Zero fruit loss – Between April and September 2022, DSC will divert 4.4 million pieces (200,000 MT) of banana pseudo-stem waste post-harvest for upcycling into banana fiber.
- b. Carbon neutrality – Preventing 200,000 metric tonnes of waste from reaching landfills, can reduce approximately 258,720 tonnes of CO<sub>2</sub> emissions.

- c. Shared value of all stakeholders – The partnership between DSC and Musa Fabric will benefit the Kasilak Foundation, marginalized communities in the highlands of Bukidnon, inmates at the Davao Penal Colony, and conscious consumers around the world. Upskilling, technology transfer, employability and sustainable fashion alternatives are key outcomes that will elevate shared values for all stakeholders involved.



Fig. 8. Fibres of purpose.

Source: <https://www.eco-business.com/zh-hans/press-releases/dole-sunshine-company-turns-banana-waste-into-fibres-of-purpose-with-musa-fabric-2/>

Edited based on “Dole Sunshine Company turns banana waste into fibres of purpose with Musa Fabric” (Dole Sunshine Company, 2022)

## 2. Applications of banana fibers in different fields

### a. Shipping cables, ropes, and cordages

Banana fibers are used to make shipping cables due to its natural buoyancy and ability to resist seawater. These natural properties have established a ready-made market for shipping cables. The fibers are also widely used for making power transmission ropes and cordage, wall drilling cables, fishing nets, lines, and other types of cordage.

### b. Sanitary pads

“SHE” is a not-for-profit organization founded by Harvard Business school graduate, Elizabeth Scharpf. Her team did extensive research to determine an absorbent alternative for chemically made sanitary pads and they chose to utilize the absorbent qualities of banana tree fibers from the pseudo-stem.

Similar efforts were made by Amrita Saigal and Kristin Kagetsu at MIT. They created low cost sanitary pads for rural women using banana pseudo-stem fiber, which is being sold under the name of “Saathi”. They source the banana fiber from a banana plantation belt near Ahmedabad, which also helps farmers derive an additional source of income from the waste. Another IIT Delhi-incubated start-up, “Sanfe”, has launched sanitary pads made from composite banana fibers that can be used multiple times.

### c. Bio-pesticides and organic fertilizers

Jalgaon is the largest banana producing district in Maharashtra State. The Tapti Valley Banana Processing & Products Co-operative Society Ltd. Faizpur situated in the Jalgaon district of Maharashtra, uses pseudo-stems to extracting the liquid present in the stem called “Sap”, which is obtained along with “scutcher” (biomass) during fiber extraction. This extracted liquid is a good source of plant nutrients such as nitrogen, phosphorous and potassium, along with growth-promoting hormones like cytokinin & gibberellic acid GA3, etc. The scutcher is also used to prepare compost or vermicompost.

### d. Banana paper

Banana fiber can be a very good substitute for wood pulp in the paper industry, as it has a high cellulose content. This will reduce the environmental impact of deforestation.

### e. Handicrafts

Banana fiber handicrafts of Kerala are famous among locals and tourists. Apart from the traditional tablemats and bags, wall hangings, and mats, products such as bags, purses, mobile phone covers, curtains, and yoga mats of different shapes and sizes are also made out of this fiber. The traditional "pattu saree" in Kerala is woven from a blend of cotton, silk, and banana fiber.

Edited based on “Banana Fibre for Sustainable Fashion and Beyond” (Kumar, 2020).

Some applications are presented in a graphical form in Fig. 9.

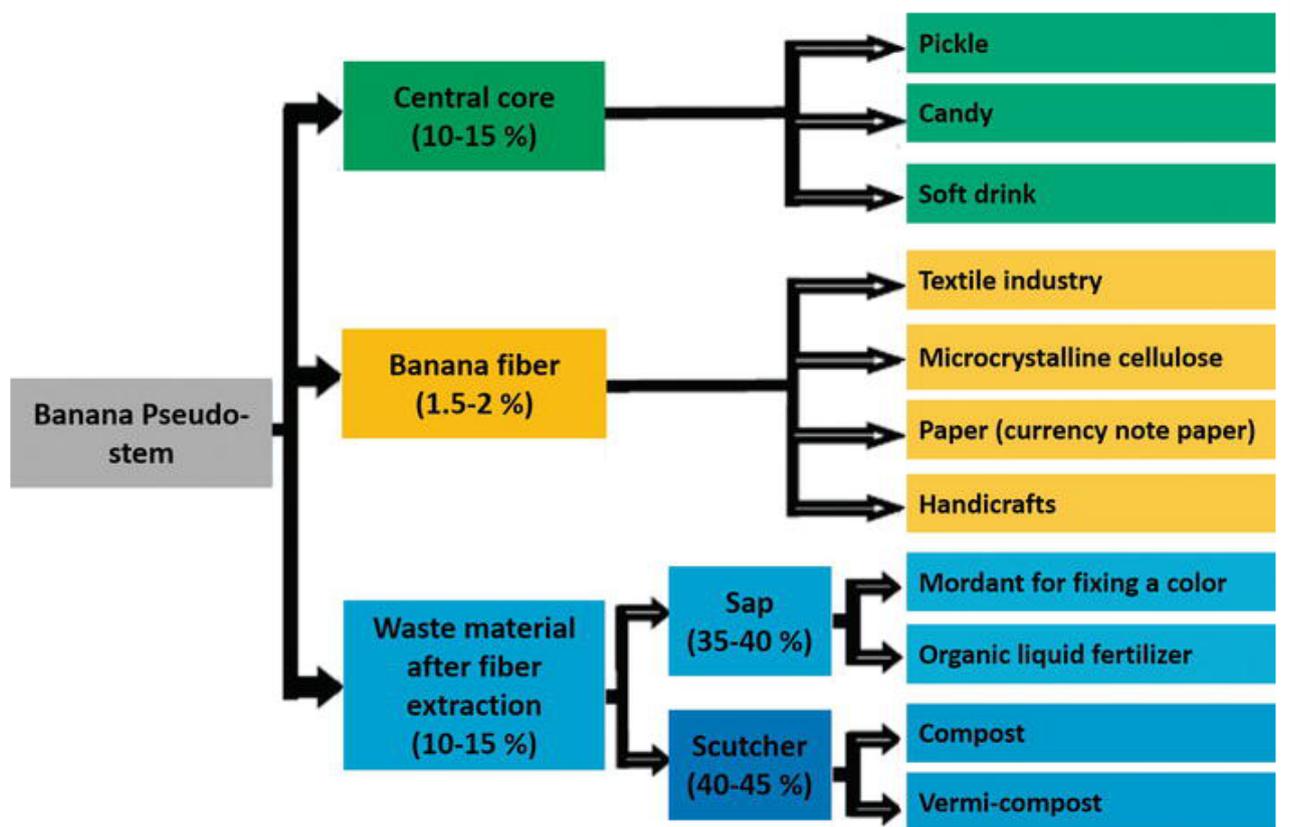


Fig. 9. Potential applications of components from the banana pseudo-stem.

Source: <https://www.intechopen.com/chapters/64570>

## Reference:

- Banana Fiber for Sustainable Fashion and Beyond. Retrieved from <https://www.onlineclothingstudy.com/2020/10/banana-fibre-for-sustainable-fashion.html>
- Banana Pseudo-Stem Fiber: Preparation, Characteristics, and Applications. Retrieved from <https://www.intechopen.com/chapters/64570>
- Design and Development of Banana Fiber Decorticator with Wringer. Retrieved from <https://www.ijrte.org/wp-content/uploads/papers/v8i1s4/A10160681S419.pdf>
- Dole Sunshine Company (2022). Dole Sunshine Company turns banana waste into fibres of purpose with Musa Fabric. Retrieved from <https://www.eco-business.com/press-releases/dole-sunshine-company-turns-banana-waste-into-fibres-of-purpose-with-musa-fabric-2/>
- Kumar, A. (2020). Banana Fibre for Sustainable Fashion and Beyond. Retrieved from <https://www.onlineclothingstudy.com/2020/10/banana-fibre-for-sustainable-fashion.html#:~:text=The%20appearance%20of%20banana%20fibre,has%20strong%20moisture%20absorption%20quality.>
- Li K, Fu S, Zhan H, Zhan Y, Lucia L. 2010. Analysis of the chemical composition and morphological structure of banana pseudo-stem. *BioResources*. 5:576-585
- Pereira, A. L. S., Nascimento, D. M., Men de Sá Filho, M. S., Cassales, A. R., Morais, J. P., Paula, R. C., ... & Feitosa, J. P. (2014). Banana (*Musa* sp. cv. Pacovan) pseudostem fibers are composed of varying lignocellulosic composition throughout the diameter. *BioResources*, 9(4), 7749-7763.
- Ray, D. P., Nayak, L. K., Ammayappan, L., Shambhu, V. B., & Nag, D. (2013). Energy conservation drives for efficient extraction and utilization of banana fibre. *International Journal of Emerging Technology and Advanced Engineering*, 3(8), 296-310.
- Waste management of pseudostem to increase the growth of banana seedlings. Retrieved from <http://www.scielo.org.co/pdf/acag/v69n3/0120-2812-acag-69-03-228.pdf>