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Mechanization in Pineapple Leaf Fibre Extraction

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ABSTRACT

The pineapple is one of the important commercial fruit crops of India. The pineapple is cultivating mainly for fruit as it contains vitamins and minerals. Pineapple leaf after harvesting fruit left unutilized in the field cause waste of natural wealth which needs to be explored. The country like Malaysia and China where pineapple cultivated in large extent has developed mechanized machines for extraction of fibre. In India, pineapple is grown in small area and lack of suitable machinery for extraction is hindrance to mechanization of extraction. Few studies have been conducted to develop pineapple leaf fibre extraction machinery in India. This paper reviews the existing conventional methods and mechanization of pineapple leaf fibre extraction along with morphological parameters of leaf which could be used for development of machinery. Further, it highlights research gaps in the mechanization of pineapple leaf fibre extraction.

Keywords: fibre extraction, decortication, manual method, mechanization

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INTRODUCTION

The pineapple is a perennial plant and a member of the Bromeliaceae family (*Ananas comosus*). The plant flourishes well in the tropical or subtropical region under humid climate. Central and South Americans were probably the first to cultivate pineapples, which later spread throughout Europe. Looking at the top ten countries producing pineapple, Costa Rica takes the first position showcasing production of 3328.1 metric tons followed by Philippines, Brazil and India stands at 6th position in worldwide production (Fig. 1). In India, pineapple acreage increased to 109.83 from 71.3 Th. ha in 1995-96. However, productivity remains stagnant at 15 Mt/ha. State-wise data indicate that Assam (14.4 Th. ha) had the largest pineapple cultivation area in 2001-02, followed by West Bengal (11.5), Manipur (10.3) and Kerala (9.8), while Nagaland (3.0) had the smallest. West Bengal recorded the highest production (322 MT), followed by Assam (220) and Bihar (101.3), while Kerala had the lowest production of 68.3 tonnes. In terms of output per hectare, Karnataka led with 40 tonnes, followed by Nagaland with 28.2, West Bengal with 28.1, and Bihar with 25. While Kerala had the lowest output with just 7.2 tonnes.

Pineapple is mainly cultivating for fruit (Fig. 2). After harvesting pineapple fruits, leaves are left unused on the Indian subcontinent, causing waste of natural resources that must be explored. In most cases, after harvesting the fruit, the plants are uprooted and remnants are left in the soil. Farmers used to burn agro waste, causing their carbon footprint to be greatly impacted. In pineapple leaves, there is a certain amount of fibrous material, known as pineapple leaf fiber (PALF). Variations in PALF properties can be attributed to its species, geographical region, age, location, and weather conditions. Fibers can be extracted from pineapple leaves either manually or mechanically. In addition to being white in color, pineapple leaf fibers are strong and soft (Nadirah *et al.*, 2012). Polymeric lignocellulosic fibers like PALF contain polysaccharides, lignin, pectins, uronic anhydrides,

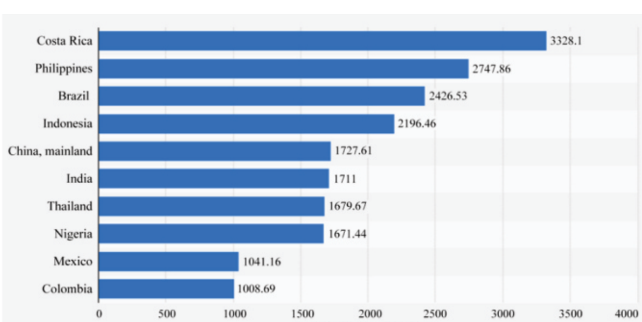

Fig. 1: Pineapple production countries [FAO, 2019].

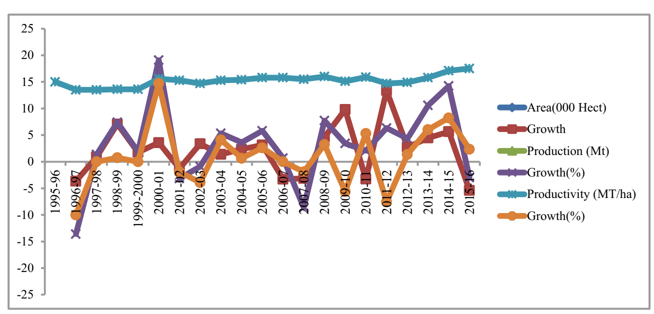

Fig. 2: Production, Productivity, growth rate of pineapple over the years

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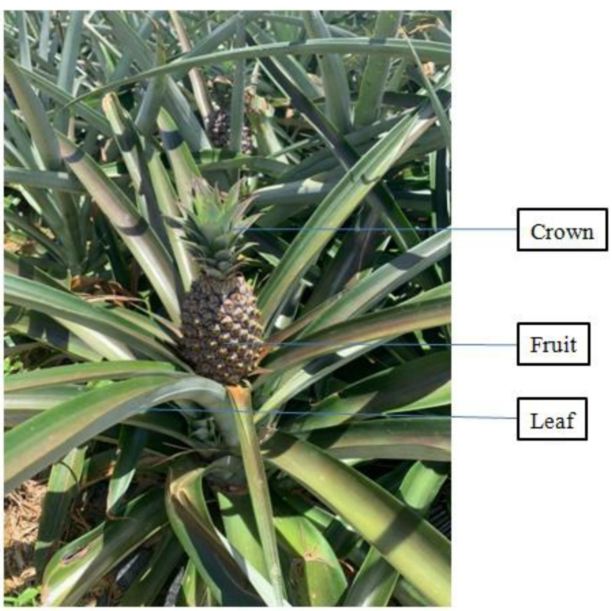
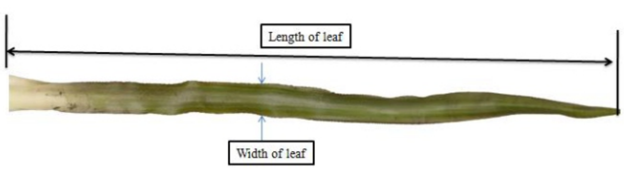
pentosans, coloring matter, as well as some inorganic compounds such as metals and inorganic compounds (Banik *et al.,* 2011). There are a variety of social, economic, and technological obstacles that prevent pineapple leaf fibre from fully being exploited, despite its potential. The lack of suitable machinery and inadequate knowledge of fibre extraction are major technological obstacles to pineapple leaf fiber extraction (Hazarika *et al*., 2017). Due to these issues, PALF remains underexploited in India. This review paper aims to identify research gaps on pineapple leaf extraction processes.

Pineapple leaf parameters

The leaves of the pineapple are strong, rough, and tapered from base to tip. Their spiral arrangement maximizes sunlight absorption (Fig. 3 a). Around the stem of the fruit, the leaves are arranged Fibonacci-style, making sure they are as exposed to sunlight as possible. After spiraling over each other, pineapple leaves mature to produce a 2.2 m^2 pineapple leaf. The leaves are also long, needle-pointed and bearing sharp spines along their margins, and their width and length are approximately 0.05–0.08 meters and 0.508–1.83 meters, respectively. Hazarika *et al.* (2017) studied the morphology and moisture content of pineapple leaf at three locations basal, middle and tip portion (Fig. 3 b). The study reported that variation in length and width of leaves with respect to location. The pineapple leaves were about 120-125 cm in length, having a surface area of 4-4.5, 154 5.2-5.5 and 0.6-0.7 cm at basal, middle and top respectively. The weight of a single leaf varies between 156 70-75 g. The moisture content plays an important role while extracting fibre from leaf. The moisture content of freshly harvested leaf ranged between 80-85 % (Zawawi *et al*., 2014). Depending on the species or type of plant, pineapple leaves have a thickness of 0.18 cm thick leaves of up to 0.27cm. Thickness of the leaves is required for setting or deciding the gap between the feed rollers and scratching roller of the pineapple fiber extractor. Further, rpm of the rpm raspador cylinder and gap between breastplate and raspador cylinder is depends on thickness of the leaf. Length of pineapple leaf could be useful for design of the conveyor or automatic system of feeding to machine.



(a)



(b)

Fig. 3: Morphology of Pineapple plant (a) and leaf (b)

Mechanization in Pineapple leaf fibre extraction

The pineapple leaf has a spiral sword shape with curved ends toward the cross section, which helps maintain its rigidity. The leaves are also long, needle-pointed and bearing sharp spines along their margins, and their width and length are approximately 0.05–0.08 meters and 0.508–1.83 meters, respectively. The pineapple leaf contains 2.5-3.5 % fibre, which is covered by a hydrophobic waxy layer (Banik, 2011). There are bundles of fibrous cells within PALF, which has a ribbon-like structure and a vascular buddle system. The epidermal tissue of the leaves can be removed to extract PALF. The fibre from pineapple leaf can be extracted by manual scrapping, retting and mechanical decortication. In this review paper, major focus is on mechanization in extraction of pineapple leaf fibre.

Manual extraction of fibre

Manual method of extraction was most prevalent everywhere before advancement in extraction machines. There are two methods of manual fibre extraction. One method involves scraping the raw leaf surface with ketam, ceramic and blunt knife edges to remove the waxy layer, followed by extraction and washing under water before sun drying. This method is applicable for long leaves (Rafiqah *et al.,* 2020). In an attempt to develop a machine to replace manual extraction Hoque (2016) designed and developed a pineapple leaf fibre extraction machine that consists of rotating gear, handle connecting rod and ceramic plate scrapper (Fig. 4). Upon rotating the handle, the ceramic plate moves forward and backward on the leaves, removing the waxy layer.

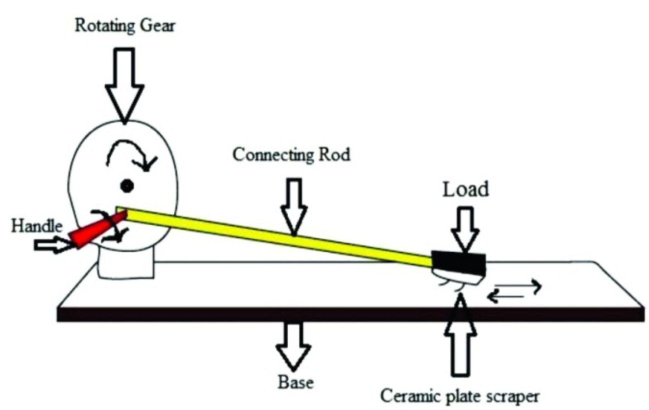


Fig. 4: manually operated pineapple leaf fibre extractor

In another method of manual extraction, the leaf is soaked in water for some time so microorganisms can remove sticky substances surrounding the fibres. After that, a ceramic edge is used to extract fibre from leaf scrapping on the surface (Fig. 5). The extracted fibres are washed and dried under the sun or using the oven. This method reduces the fibre loss, increases quality as well as quantity of extracted fibre. The manual immersion method yielded good spinnable quality fibre after 18 days of immersion. In manual extraction, it was reported the fibre yield was up to 3–4%.

They are time-consuming, tedious, and prone to allergies. Rafiqah et al. (2020) reported that thirty manpower are required to extract one ton of leaves. Although, manual method produces better quality fibre than mechanical extraction, yield is less and scalability is problematic.

Fig. 5: Manual extraction of pineapple leaf for fibre

Mechanical extraction of PLF

Around the world, pineapple is available in many varieties that suit different agro climatic zones. Fruit is one of the main reasons they are grown. There have been attempts to use fiber extracted from waste leaves. There are few research articles on fibre content with respect to variety. With the objective of investigating fibre production from two varieties of Malaysian grown pineapple, Mazalan and Yousuf (2017) observed significantly higher dry fibre production for the josapine variety compared to the moris variety in a machine called a pineapple leaf fibre decorticator.

Mechanical extraction of pineapple leaf fibre involves beating and scrapping of roller by rotating element followed serration on scrapped leaf by secondary roller. A pineapple leaf fiber decorticator machine with leaf grinding principles has been developed by Weisdiyanti *et al.* (2019). The machine has two stages of grinding and has a capacity of 0.12 kg/hr for dry fibre. Banik *et al.* (2011) reported the pineapple leaf extraction machine consists of feed roller, scratching roller and serrated roller (Fig. 6). The function of scratching and serration roller removes the waxy layer and crushes leaves for better retting by microbes. The capacity of the machine was 1500 kg green fibre per day (Das *et al*., 2010). The researchers also studied the retting of machine-extracted pineapple leaf against manual combing, and found machine scraping leaf retting took six days as opposed to 10 days with manual combing. In another study conducted by Nayak *et al.,* (2016) conducted retting of machine extracted pineapple leaf with bacterial cultures and found that bacterial culture reduced retting period to 3 days compared to control (10 days).

Fig. 6: Pineapple leaf fibre extractor

Joseph (2021) design and fabrication of a pineapple leaf fibre extracting machine comprised of fixed roller and raspador rotor. The machine has provision to adjust gap between rotors based on pineapple leaf size. The PALF extractor is powered by an electric motor of 3 hp and had an efficiency of 52.08 % with a throughput capacity of 5.24 kg/h of fibre.

Yusof *et al.* (2015) have developed a novel decorticator machine for the extraction of pineapple fiber using beating and scrapping principle of working. In this extraction method, the blades of decorticators scratch the surface of the leaves to remove some waxy layers. The leaves were then pulled from the machines using hand, and most of the waxy coating was removed. After the fibers were extracted, they were cleaned and dried. Similar kind of machine was designed and fabricated by Majlish (2020) for banana stems and pineapple leaves consists of pair of feed roller and decorticating cylinder. Shakyawar *et al.* (2021) reported an ICAR-NINFET developed improved pineapple leaf fibre extractors that comprised a feeding roller, scraping roller, and combing roller. Combing and scraping were designed to enhance microbe penetration into processed leaves. One horsepower electric motor operated the extractor, which could process four green leaves simultaneously, resulting in a capacity of 30 kg leaves per hour and an average yield of 1 kg dry fibre per hour (fig. 7).

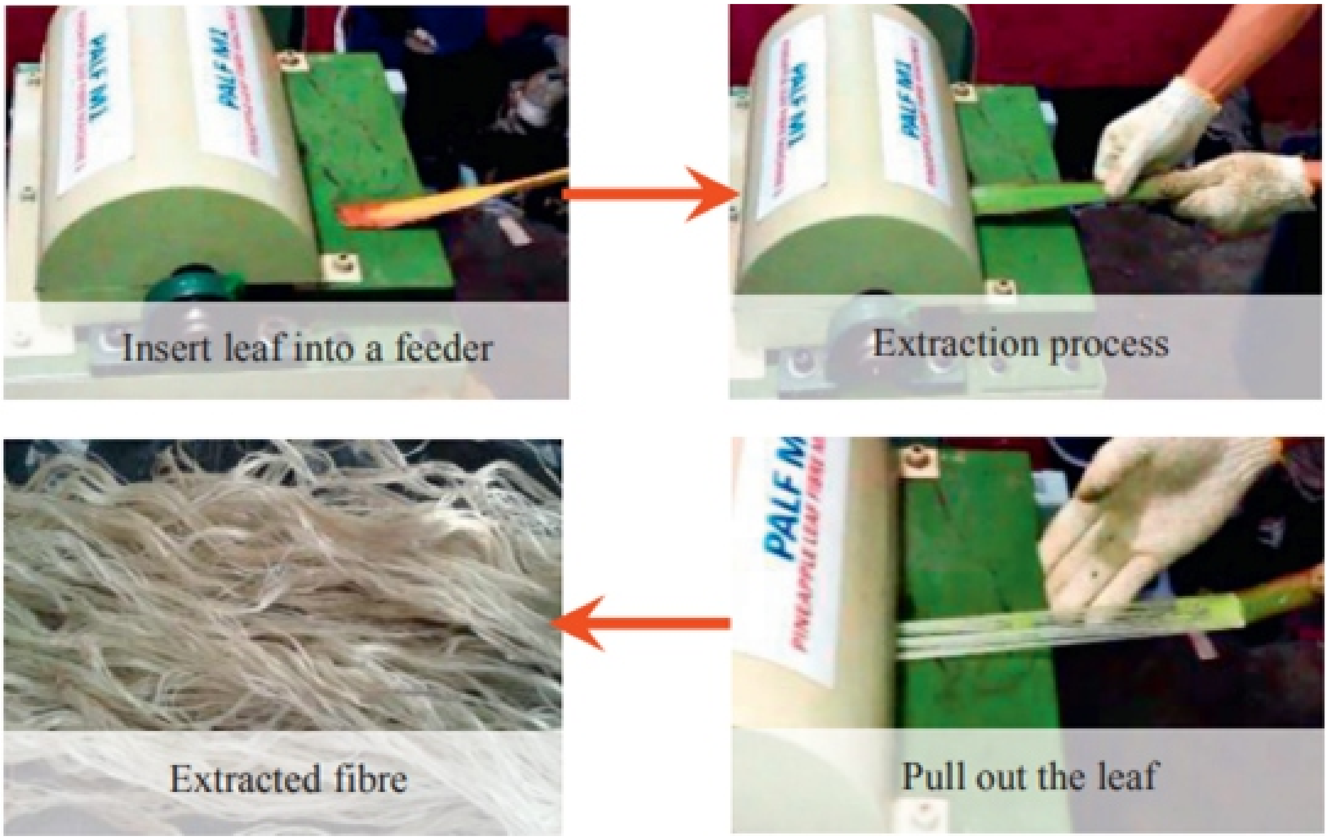


Fig. 7: Pineapple leaf fibre decorticator

Sarah *et al.* (2017) used semiautomatic pineapple leaf fibre extractor having "roller and bladder" machine system. The pineapples are feed to beating roller and pushed back to remove waxy layer of leaf. The extracted fibre was compared with other methods and found mechanical extraction by roller and bladder had high tensile strength and high removal of amorphous lignin was obtained. Apart from the decorticator, the angle of feeding, feeding position and surface of the leaf also affects the time taken to extract, quality and quantity of fibre. Adam *et al.* (2014) evaluated a pineapple leaf fiber extraction apparatus under different feeding angle (0, 18, 45, 72 and 90°). The results revealed that as the increases from 0 to 90, time taken to extract fibre decreased. The best angle to reduce time associated to 45 °.

Few studies have been dedicated to the development of a pineapple leaf fibre extraction/decortication machine (fig. 8). Automatic pineapple leaf fibre extractors are available in Malaysia and china. However, there was no detailed analysis of the performance of the developed machine for producing quality fiber from pineapple leaves. Besides machine, crop parameters like moisture content, optimal age of plant for extraction, position of the leaf in the machine also have a bearing on the quantity and quality of fibre. Due to the fact that farmers are unaware of the fibre in pineapple leaves, they

Fig. 8: Improved pineapple leaf fibre extractors

waste this fibre by dumping it or burning it after they have dried the leaves. Moreover, it is grown only in a few pockets of India, and that too for fruit rather than fiber. The use of pineapple leaf fibre for the production of diversified products needs to be made known. The development of multi fibre leaf extractor need to be developed to reduce the burden of purchasing separate machine for pineapple.

CONCLUSION

A review of available literature on various aspects of traditional as well as mechanical extraction of pineapple leaf fibre was carried out. Few research works have been happened to develop pineapple leaf fibre extraction. Commercially automatic pineapple decortication machines are available for large growing farmers. Other developed nations have already achieved high level of mechanization. However, pineapple in India grows in pocket size area and mainly for fruit purpose. The development of decortication/leaf fibre extractor suitable for small and marginal farmers is need of the hour. Further the use of pineapple leaf fibre for the production of diversified products needs to be made known.

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