PULP AND PAPER PRODUCTION FROM PINEAPPLE LEAVES AS A SUBSTITUTE TO WOOD SOURCE: A REVIEW

[1]Saurabh S. Mahatme , [2]Nitin G. Kanse, [3]Annasaheb K. Bandsode
[1] B.E. Student, [2]Asisstant Professor, [3]Asisstant Professor
[1]Chemical Engineering Department
[1]Finolex Academy of Management and Technology, Ratnagiri, (Maharashtra) India

Abstract : In developing countries, there are different approaches to deal with organic waste. One of the approach from commonly used fruits is Pineapple. Considering an example from each pineapple fruit, only 52 % is used for jam and juice production and remaining 48 % consists of fruit peel and leaves forming the waste. These waste are rich in lignin and cellulose and form a very good raw material for allied fibers. Also, waste disposal is a major problem in these industries because of very high lignin and cellulose content of the waste leaves, which is difficult to be degraded, thus results in pollution and affects the environment.Natural fibres from non-wood materials are important resources to meet the increasing demand for pulp and paper products.The main purpose of this review is to highlight the potential of pineapple leaves used as non-wood materials for paper production. From other prospective, PALF can be an essential raw material to industries, which can be replaced for non-renewable synthetic fibre, which are expensive and also largely available waste material. A manufacturing process of pulp and paper is discussed in this review. Furthermore, a detail study of chemical property will show proper utilization of PALF for different applications is discussed in this review.

IndexTerms - **Pineapple Leaf, Fiber, Pulp, Paper.**

I. INTRODUCTION

Pineapple (*Ananas comosus*) is aremarkable fruit of India. The information provided by (IH) Database, suggests, in India pineapple is cultivated in 115 thousandarea andtotal production is 1,988 thousand tons up to year 2017[2]. The main origins of Pineapple is in the South American content. Thailand is one of the world's top growers of pineapples, with approximately two million tons of production per year, some of which is processed into canned pineapples, which has also become one of the country's major commercial export items, with more than 5,00,000 tons of finished products per year. Thai people consumes fresh pineapples, while cooking with their meals or as a snack.Its long, tough leaf fibers make good raw materials for the paper-making industry; its hull can be processed into animal feed and fermented organic fertilizer. By industrial process, factories produce large leftover raw pineapple fibers per day. The majority of them is sold to farmers, who will use to mix with animal feed.Due to a large amount of leftover every day, Asst. Prof. Sudjaya Ritsorn, fromRajamangala University of Technology Thanyaburi, conceived the idea of converting these fibers into handmade paper which can increase their commercial value as well as create jobs for villagers. One sheet of finished pineapple fiber paper can sell much higher than the price of raw fibers sold as animal feed. Therefore, this study aims at investigating the suitability of pineapple leaves in pulp and papermaking. The overall outcome of pineapple leaves can be used as an alternatives fibres in pulp and paper making industry.Pineapple leaves are cellulosic, abundance agro-waste of pineapple industries with chemical composition of high cellulose contents. Good mechanical properties, renewable resource, and low cost fibers are the main factors that lead to high potential of pineapple leaves fibers to be used as alternative raw materials in paper industries.

In India it is abundantly grown in almost entire North East region. As referred the main contributing states in the production of Pineapple areAssam, Manipur, Tripura and Meghalaya. As an advantage the North East region has fertile and organically rich soils, plenty of rainfall, great climatic diversity and water resources. Pineapple leaf contains 2.5-3.5% fibre, covered with hydrophobic waxy layer. The fibre extraction alone from the leaves is not economically feasible, therefore utilization of residual sludge remained after the process can be done in vermicomposting and other applications. In Tripura, the South Indian Textile Research Association authorized a pineapple leaf extraction plant. The immensecapacityfor producing better crop quality and fulfilling the needs of the people in this field as the scope for emerging marketis in the North East region [2].

II. PINEAPPLE

2.1 Pineapple Plant

Pineapple is from family of Bromeliaceaehaving height and width of 1-2m, which is mostly cultivated at tropical and coastal regions, mainly for fruits purpose. In India, the cultivationis on about 95 million hectares of land and increasing its production. Figures 1(a) and 1(b) shows pineapple plant has a short stem with dark green colour. First sprout of leaf looks decorative; later the size converts into 3 ft. longsword shaped and spirally arranged fibrous leaves and its edges are curved towards the cross section, which maintains the stiffness of the leaf. Onouter shell of each Pineapple fruit it has equal number of hexagonal sections,which does not depend on shape or size. In Asia, India is a largest country to produce pineapple plant. It produces a huge amount of waste material. Pineapple contains rich source of bromelain and other cysteine proteases, present in different parts of pineapple. Commercially, bromelain has been used in many food industries, cosmetics, and dietary supplements. In 2013, India produced 1.53 million Tonnes of pineapple with productivity of 15.3 tonnes/hectare[3].

2.2 Chemical Composition

As per Technical Association report of Pulp and Paper Industry standards (7) the chemical constituents like lignin, wax, pectin, ash content, nitrogenous matter, α-cellulose, degree of polymerization, antioxidants of PALF were analysed from different sources of fibres, climatic conditions, and age of fibres. It has a large quantity of α-cellulose, lignin content, and low quantities of hemicelluloses. PALF has higher cellulosic content compared to other natural fibres like coir, banana stem fibres which suggest the truth of higher weight of the fruit. The performance of fibres is directly affected by the chemicals composition fibre.

Chemical Composition of Pineapple:

Nutrients	Units	Value per 100 g
Water	g	86.00
Protein	g	0.54
Total lipids	g	0.12
Ash	g	0.22
Carbohydrates	g	13.12
Fibre	g	1.4
Sugar	g	9.85
Sucrose	g	5.99
Glucose	g	1.73
Fructose	g	2.12
Vitamins		
Vitamin C	mg	47.8
Vitamin A	IU	58.0
Others		
Carotene	µg	35

Source: USDA Nutrient Database

2.3 Historical Background

America inhabitant plant is Pineapple, by going through history it was first seen by Columbus and his companion in 4th November 1493, at an island of West Indies. Pineapple has been spread all over South America coastal region as well as in tropical regions. A Spanish government officer named as De Oviedo came to America in 1513 to hand over first written documents of some varieties of pineapple,which includes some Indies varieties too. The plant is called pineapplebecause of its fruit, which look like pine cone. The native Tupi word for the fruit was *anana*, which meansexcellentfruitthis is the source for words like *ananas*. The pineapple is an old emblem of welcome and seen in stamped decorations. Its exotic features and rareness in 17th century Americans imported pineapple fruit from Caribbean. Pineapple is considered as an icon of wealthy people in America. The Portuguese introducedpineapple throughout the whole tropical regions and major parts of world like south and east Coast of Africa, Madagascar, south India, China, and Philippines. Nowadays, pineapple plants are used in various applications such as medicinal, edible, and industrial purposes. For example, bromelain extracted from leaves as an enzyme, helps in respiratory ailments. Dehydrated waste material of pineapple can be used as bran feed for chicken, pigs, cattle. A mixture of pineapple juice and sand is powerful cleaner for boat decks [3].

2.4 Pineapple Leaf Fibre

Yearly plenty of pineapple leaf fibre is produced but very small portion are used for feedstock. As an industrial usage the expansion of bio-composites makes the possibilities to minimize the wastage of renewable materials and promotes a non-food based market for agricultural industry. The fibre is white in colour, glossy as silk, and smooth shown in Fig 1(c). Medium length fibre has high tensile strength as compared to small length. It surface is soft if compared to other natural fibres also absorbs and maintains a good colour. Pineapple leaf fibre has high strength and stiffness and is hydrophilic in nature, which has high cellulose content. As per report extraction of fibres from pineapple leaves are carried out mechanically. Their fresh leaves yield about 2 to 3% of fibres. After mechanical removal of the entire upper layer obtained fibrous cell of PALF consists of vascular bundle system, which are in the form of bunches. Pineapple leaf fibre composed of many chemicals constituents. It is multicellular lignocellulosic fibre containing chemicals like fat, wax, pentosan, pectin, uronic acid, anhydride, colour pigment, and inorganic substance, polysaccharides, lignin in major amount. Fibre is nothing but a collection of thin and small multicellular threads, which are tightly joined with the help of pectin. PALF mainly constitute cellulose (70–82%) and arrangement of fibres is the same as in cotton (82.7%). Pineapple leaf fibre is more compatible natural fibre resource and constitutes a good chemical composition and it also has better mechanical strength compared to jute, used in making of fine yarn. Cellulosic molecules model of PALF is a three-dimensional structure and parallel to crystalline region of the fibre. Remaining parts of molecular structure are supposed to associate within amorphous regions. Industries use it as an outstanding alternative raw material for reinforcing composite matrixes. Pineapple leaf fibre is essential natural fibre, which has flexural and torsional rigidity as much as jute fibres, high specific strength [3].

(a)Pineapple ground

(b) Pineapple Fruit

(c) Pineapple leaf fiber

(d) Extraction of fiber

III. MATERIALS AND METHODS

There are several raw materials like banana fibre, wheat straw, baggase, rice straw from which paper is manufactured by the traditional methods of fiber extraction which involves the processes viz., scrapping, retting, decortication, combing etc., that takes up to 5-7 days.

3.1 Raw Material

At first process pineapple leavesare collected from the bunch of freshly harvested pineapple fruits obtained from local pineapple stores.The samples are washed, sorted and cut into chips of about 2-4cm, sun dried and sorted in bags.

3.2 Extraction

Decortications

It is difficult to extract the fibers as they are sticky due to the presence of pith thus making necessary for use of chemicals which is not Eco safe. Thus, there is an urgent need for the development of eco-friendly, cost effective technology.

Retting

The scratched leaves are being tied and immersed in a retting tank. Urea or diammonium phosphate added for quick retting. At the end of retting, leaves are taken out and washed mechanically by pond water (2).

Scrapping

PALF) pineapple leaf fibre is scrapped by scrapping machine. The machine contains combinationof three rollers: (i) feed roller (ii) leaf scratching roller and(iii) serrated roller. The leaves are fed through feed rollerinto the machinethen it go through the second roller that is called scratching roller, which scratches upper layer of leaf to remove the waxy layer and lastly leaves come to the dense attached blade serrated roller, which crushes leaves and makes several breaks for the entry passage for the retting microbes (2).

Fig. 2: Scrapping operation through rollers

3.3 Pulp Washing and preparation

The obtained pineapple leaf pulpwas washed under running water to remove the residual chemicals present and the pulp samples weredisintegrated in a laboratorysteel blender, which act as a wet disintegrator. The pulp was moulded using mold and deckle. Thepaper was dried in the oven at 60◦C till the pulp fully dries. Finally, the paper was pressed using the compression moulding machine at 100◦C to get eventhickness of paper sheet.

3.4 Pulp bleaching

A weighed amount of dried pulp was introduced into a beaker, and measured amount of Hydrogen Peroxide (H_2O_2) was added. The beaker was then heated on a hot plate for about 20mins after, which has to be observed for the colour of the pulp changed to white.

(a)

(b)

Fig. 3 (a) & (b) Pulp Bleaching and Bleached pulp

The process begins with sun-drying raw pineapple fibers, before soaking them in water. Then the fibers are placed for two hours in a Sodium Hydroxide solution, at 80 to 90 degrees Celsius, and rinsed with water for cleaning of residue. The cleaned fibers are then bleached in a hydrogen peroxide solution and washed for cleaning again before framing into sheets.After that, the blended ingredients will be placed on the nets of a wooden frame. The frame is made of wood and a fine web which seeks to remove the liquid content contained in the material. After that, the paper will be dried at room temperature. Finished paper has outstanding toughness, smoothness, and transparent properties. These sheets features beautiful fiber patterns and has higher quality compared to industrially produced papers. Sheet can be fashioned into crafts, such as paper flowers.

3.5 Laboratory analysis of paper sheets

As per report the paper samples are then tested for strength properties such as modulus of elasticity, elongation at break, tensile stiffness, tensile strength and tear strength. These values are used to obtain the tear index and tensile index of the various paper samples.

3.6 Mechanical Properties

In bio-composite and material science, reinforced natural fibres composite plays a big role. PALF has been a good substitute of synthetic fibres, because of its economic and renewable nature. The strength of natural fibres supports to enhance physical and mechanical strength of polymer matrix without any additional processing. The mechanical properties of PALF is related with low microfibrillar angle and high content of alpha cellulose. PALF has extraordinary qualities that can be used as reinforcing composite matrix.The physical and mechanical properties of any natural fibres mainly dependsupon volume fraction of fibre, fibre-matrix adhesion, orientation, aspect ratio, and stress transfer efficiency at interface.

IV. FACTORS AFFECTING PAPER PRODUCTION AND CHARACTERISTICS

4.1. Turbidity

The quality of pulp is identified byits strength, ability of bleach, high cellulose and hemicellulose content and low lignincontent. The literature indicates that when the acetone concentration is increased the turbidity also increases dramatically, which means a large amount of lignin was precipitated at low acetone concentration. Below acetone concentration, the turbidity was low, which is an indication of low content of lignin dissolved.

4.2 Tearing resistance

Equivalent to the turbidity test, where less lignin has beendissolved in the solvent as a consequence, higher amountof lignin remaining in the paper sheet causes the paper tobecome brittle and hence constitutes to lower strength properties.At longer soaking time the improvement in paper strength is aresult of low lignin content. Thusthe temperature and pressurehave positive effect on paper strength and more lignin wasremoved from pineapple leaves. These conclude that the tearing strength of the paperis dependent upon the lignin content, where the reductionof lignin increases the tearing resistance and produced better paper quality (5).

4.3 Fiber characteristic

Table 1. Mean Value of Fiber Characteristics for the solid-wastes (6).

Sample	Fiber Length Diameter (μ m)	Fiber Width (μ m)	Lumen thickness (μ m)	Cell Wall Ratio	Runkel of Flexibility	Coefficient Ratio	Slenderness Power	Felting
Ananas Comosus	0.935	30.63	19.10	5.766	0.6390	62.348	30.527	2.6559
Tithonia Diversifolia	0.758	25.20	16.00	4.416	0.5395	64.956	30.063	2.8536
Cocos Nucifera	0.894	16.49	8.10	4.194	1.6574	51.848	54.202	2.2435
Sansevieria Liberica	2.291	23.19	12.15	.518	0.9226	52.349	98.780	2.1142

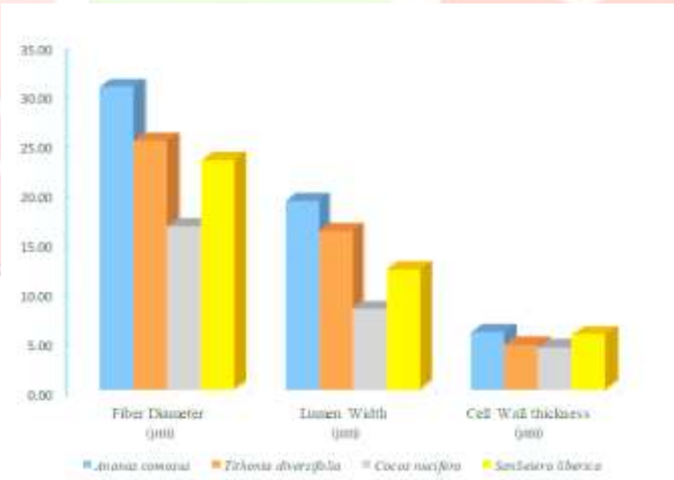

Fig.5: Comparison of the diameter, lumen width and cell wall thickness of the fibers

Table 2. Chemical composition of Pineapple leaves

Agro waste	Pulp yield (%)	Cellulose (%)	Ash Content (%)	Lignin content (%)	Moisture content (%)
Pineapple leaf	15	65	1.2	11.5	81.6

The composition of pineapple leaves shows cellulose, as a major chemical component of fiber wall. Important parameters for suitability of a raw material of pulp and papermaking is cellulose component of the fibre inside non-wood materials, which makes it stronger and the quality of fibre extracted depends upon the cellulose contents, hemicellulose, and holocellulose. Higher contents of cellulose makes stronger fiber, thereby increases the quality of the paper formed. The table shows pineapple leaf contains low lignin of approximately 12%. The main advantageof the low lignin content isthe use of non-wood materials in production of pulp, which requires small amount of chemical for pulping and functions as adhesive to bind the cellulose fibre together. Lower lignin content is easier to get rid from the pulp, and the paper produced is of greater quality compared to other non-wood materials. Pineapple leaf has lower ash content (1.2%)whose function is to show the absence or presence of other materials slightly or in combination. The low ash content indicates that pineapple leaf pulp has the potential to produce good quality paper. Pineapple leaf has very high moisture content (81.6%). This high moisture content will affect the mechanical and surface properties of the paper produced which indicates a less dimensional stability against the grain. Cellulose fibre can swell from 15 to 20% from dry condition to saturation where it can cause the change in dimension stability. Such change in dimension will make the dimensional stability decrease cause the undesirable cockling and curling in the dimensional stability of the paper. Quality paper needs a very good dimensional stability against the grain because the structure and the strength of the paper depend on it.

Table 3. Result of paper characterization from different noon wood materials

Agro wastes	Grammage	Thickness	Tensile index	Tear index	Modulus of elasticity	Elongation at break
Pineapple leaf	45.62	0.24	0.19	17.19	5.87	1.14

4.4 Paper characterization (Tensile strength of paper sheet)

The analysis like mechanical and strength of paper represent the intrinsic chemistry, morphology, and structure of the individual fibres also the network structure of the paper. Factors influencing the properties of paper sheets produced from any pulp are residual lignin, impurities, pulp consistency, degree of pulp beating, relative humidity of the environment. The fiber dimensions, strength, arrangement, and the limit up to which they are bonded to each other are some important factors for characterization.

4.5 Surface Morphological Analysis

While producing the paper scanning electron microscopy (SEM) analysis of pineapple leaf papers are done. By literatureit shows that higher the magnification the clearer the fibre structure and the lower the magnification the smoother the coverage. Further the pineapple leaf had the smoothest coverage and a clearer fibre structure, which makes pulp a best substitute to wood in paper and pulp production.The results obtained from the report shows that therewere large fiber bundles in the paper sheets, being orientatedin various orientations. The large fiber bundles were madeof a number of technical fibers that were made of even finerelementary fibers of below 10 m diameters. This is because, the fiber extractionfrom dried leaves proved difficult with more tissues presenton the surface and fine fibers torn from the bundles. While drying, the leaves also made it almost impossible to remove thetechnical fibers from the bottom face of the leaves. From the colour of the fibers it is observed, in addition to the brown colour of lignin particleson the fibers, many other parts of the paper appear brownish.This indicates that some lignin, although not in particle formor not being observed by the light microscope, exists in the fiber wall. For instance, the acetone is not nearly as strongas caustic, which can shorten the fiber lengths and led to poorsurface appearance of the paper sheets(6).

V. APPLICATIONS OF PAPER

Paper can be produced with a wide variety of properties, depending on its intended use

1. For representing value: paper money, bank note, cheque, security, voucher and ticket.
2. For storing information: book, notebook, graph paper, magazine, newspaper, art, zine, and letter.
3. For personal use: diary, note to remind oneself, etc.; for temporary personal use: scratch paper.
4. For communication: between individuals and/or groups of people.
5. For packaging: corrugated box, paper bag, envelope, Packing & Wrapping Paper, Paper string, wallpaper.
6. For cleaning: toilet paper, handkerchiefs, paper towels, facial tissue and cat litter.
7. For construction: papier-mâché, origami, paper planes, quilling, paper honeycomb, used as a core material in composite materials, paper engineering, construction paper and paper clothing.
8. For other uses: emery paper, sandpaper, blotting paper, litmus paper, universal indicator paper, paper chromatography, electrical insulation and filter paper.

CONCLUSION

The pineapple leaf fibre in composite material is a new source, which can be economic, eco-friendly, and recyclable. Based on the survey the paper made from pineapple leaf fibers, and old newspapers has the basic properties of paper could be written, can be torn and can absorb moisture, which is basically suitable for the paper. As a way of converting waste to wealth, the research is expected to put value on the solid wastes. Farmers will obtain more revenue and also play a prominent role in getting rid of the environment from the huge solid wastes generated by the poor disposal of these agro-wastes. However, when evaluating the terms of thickness and other features found on the paper produced, it can only be used as the medium of packaging such as boxes at this time. The mechanical properties and chemical properties of natural fibers are very useful in the manufacturing sector. In conclusion, the results of the latest technologies, development of natural fibers as a material to be done and improved in various forms of applications and usage. It is also expected to provide raw materials for investors and employment opportunity for people since it will be a start-up industries to save capital and encourage establishment of processing mills in rural areas.

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