A New Approach for PALF Productions and Spinning System: The Role of Surface Treatments

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***Abstract*—In agricultural sector, there is an environment and technical issue during disposal process of agro waste after harvesting. Nowadays, there are some efforts being made worldwide in order to promote agricultural waste in a series of value-added products. The establishment of high-performance materials made from natural resources is a good approach towards developing sustainable agriculture sector. One of the potential fibers from agricultural waste developed in Malaysia is pineapple leaf fiber (PALF). An extensive research showed PALF have been successfully performed in textiles industry and reveal PALF immense potential in yarns productions. This work presented the new technology invented for PALF productions. The comparison of tensile properties between PALF extracted by hand scrapping and PALF M1 are evaluated. Besides that, the effect of alkaline and heat treatment towards PALF tensile properties also being studied. Obviously, the PALF extracted using PALF M1 experienced higher tensile than PALF extracted by hand scrapping. Furthermore, it was found that both treatments substantially increased PALF tensile strength. Further investigations is required in order to determine the effect of fiber properties and linear density on PALF yarn hairiness in spinning system.**

***Index Terms*—agricultural waste, sustainable, pineapple leaf fiber (PALF), technical yarns, PALF spinning.**

I. Introduction

Pineapple is broadly cultivated for its delicious fruit in tropical and subtropical regions of the world. Pineapple leaves, the major part of the plant which is currently unused needs global attention for its commercial exploitation. After fruit harvesting, the leaves are disposed by burning or decomposed. Besides just wasting source of high potential fibers, burning and decomposed also led to environmental pollution, soil erosion and decreased soil biological activity. Pineapple waste is no longer something that is unwanted. Recently, it is regarded as resources for economy development. Turning pineapple leaves into wealth not only makes good environmental sense, but also turns "trash" into "cash".

Regarding to these concerned, there are few research carried out to figure out the possibility adding values to pineapple leaves. The discovery of pineapple leaf fibers potential in 'new markets' area not only proposed the solutions to environmental issues, but provided a potential for the mass consumption of these resources with applying some technologies besides generate extra income for the farmers and pineapple entrepreneurs.

Pineapple leaf fiber (PALF) can be obtained from the pineapple leaves either by scrapping, retting, or decortications and used for significant purposes without any additional cost input. PALF is white, creamy and lustrous as silk fiber and is 10 times as coarse as cotton. In addition, these fibers can easily retain dyes. PALF contributed with excellent mechanical properties compared to other natural fibers hence make it as an effective raw material in textiles manufacturing by binary or multi blending [1]. A comprehensive study need to be done in order to investigate the possibility of using PALF on existing fibers spinning system. This paper is an endeavor for the PALF extractions, PALF characterization, and possible methods available for PALF spinning by using existing fibers spinning system.

II. Materials and Methods

A. Raw Materials

Pineapple leaves from Josapine cultivar were collected from cultivation area at Pontian, Johor. In Malaysia, leaves from Josapine cultivar yield the best fibers in term of fineness, mechanical properties, and thermal stability [2]. Fresh leaves collected after harvesting were directly extracted within three days in order to good quality fibers by using pineapple leaf fiber extraction machine (PALF M1). The extracted fibers is then scoured and dried by using pineapple leaf fiber scouring machine (PALF M2). PALF extraction machine PALF scouring machine are shown in Fig. 1.

B. PALF Treatments

There are three kinds of treatments applied that is alkaline treatment (Na_2CO_3), heat treatment (boiling water @ 100℃), and combination of alkaline and heat treatment. Untreated PALF was immersed in 3% Na_2CO_3 for one hour and washed several times with distilled water to neutralized the remaining alkali and marked as alkali treated PALF. For the heat treatment, the PALF was boiled at 100℃ for one hour. This sample is marked

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as heat treated PALF. All the treated PALF is then dried directly under the sun. Lastly, in case of combination treatment, the PALF is first boiled at 100℃, then sun-dried before being immersed in in 3% Na_2CO_3 for one hour and dried once again. This sample is marked as coupled treated PALF.

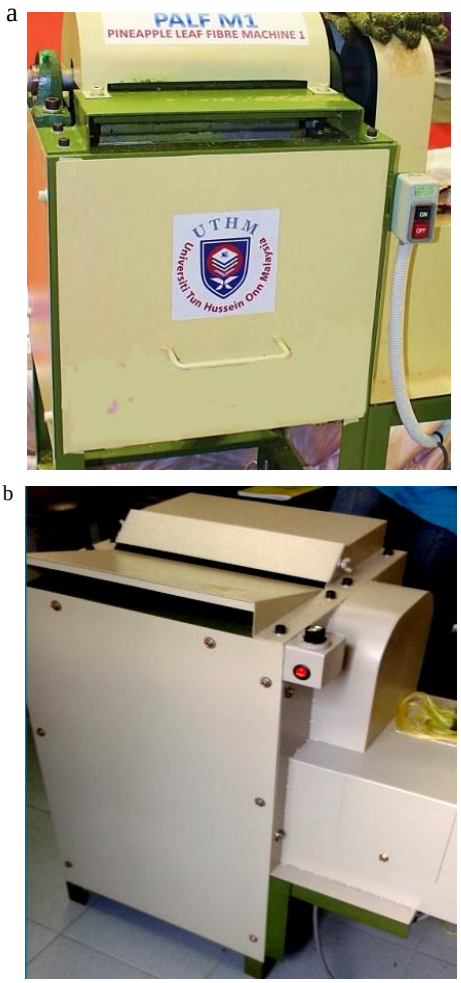

Figure 1. (a) PALF extraction machine, (b) PALF scouring machine

C. PALF Characterizations

Diameter of PALF extracted by hand scrapping and PALF M1 are measured using video analyzer. The diameter was measured at four different points and the average was calculated.

On the other hand, PALF tensile properties were determined by using Lloyd Instruments Universal Testing Machine model LR30K according to ASTM C1557-03 [3]. The specimens were pulled in uniaxial tension with 10 N load cell at a displacement rate of 1mm/min.

III. Results and Discussions

A. PALF Diameter

The average diameter of both treated and untreated PALF extracted using PALF M1 was 75.7 µm meanwhile the average diameter of PALF extracted by conventional method was 90.7 µm. PALF M1 produced more fine and thin fibers.

B. PALF Tensile Properties

The comparison of tensile properties between PALF produced using conventional methods (hand scrapping + sun dried) and new invention (PALF M1 and PALF M2) is being summarized in Table I. Obviously, the new invention of PALF M1 and PALF M2 produced more quality fiber in term of tensile properties.

TABLE I. Comparison Between Hand Scrapping and PALF M1

Productions Method	Tensile Strength (Mpa)	Young's Modulus (Gpa)	Strain to Failure (%)
PALF M1	613.75	1379500.0	6.67
PALF M1 + PALF M2	572.67	1275600.3	4.86
Conventional methods	393.70	7254.2	3.24

PALF extracted by PALF M1 showed higher tensile strength and modulus (613.75MPa, 1379500.0GPa). Even though the tensile strength and modulus of PALF extracted using PALF M1 and dried using PALF M2 slightly decreased (572.67MPa, 1275600.3GPa) from PALF M1's PALF, it's still higher compared to PALF's tensile properties produced by conventional methods (393.70MPa, 7254.2GPa).

This showed that PALF M1 and PALF M2 contribute better approach for pineapple leaf fiber extractions compared to conventional methods since it does not cause high damage to PALF properties.

On the other hand, mechanical properties of untreated and treated PALF extracted from both methods are shown in Table II.

TABLE II. Tensile Properties of Treated and Untreated PALF

Extractions method	Treatment	Dia. (µm)	Tensile properties		
			Tensile strength (MPa)	Young's Modulus (GPa)	Strain to failure (%)
PALF M1	*Untreated*	75.7	613.75	1379500.0	6.67
	Heat		671.64	6725.4	3.16
	Alkaline		763.60	2899.9	3.60
	Coupled		1088.6	6441.6	3.79
Hand Scrapping	*Untreated*	90.7	393.70	7254.2	3.24
	Heat		519.39	1408.8	3.17
	Alkaline		551.49	1640.3	4.83
	Coupled		312.10	2155.3	2.71

For PALF extracted using PALF M1, it is apparent that the PALF treated with alkaline treatment and heat treatment (coupled treated PALF) exhibits highest tensile strength compared to other samples, whereas the failure strain of the coupled treated PALF is quite similar from those treated fibers. Heat treatment did not significantly enhance the PALF tensile strength. In summarize, surface treatments will increase the tensile strength of the fiber.

However, tensile properties of treated PALF extracted by hand scrapping do not significantly enhanced by surface treatments. It is apparent that the tensile properties of coupled treated PALF (312.10MPa, 2155.3GPa) are much lower than untreated PALF

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(393.70MPa, 7254.2GPa). For hand scrapping PALF, alkaline treatments exhibited the highest tensile strength compared to other samples (551.49MPa).

IV. PALF Spinning System

Until now, there is no special system have been designated for PALF spinning system. Regarding to this concern, PALF is twisted into rope instead of yarns. However, PALF still can be spun into yarns using existing fibers spinning system by binary or multi blending. In India, various combinations of PALF blended with other fibers have been tested on different spinning systems [1]. Among the spinning systems used are included jute spinning system, cotton, semi-worsted and flax system with some special techniques applied. On the other hand, 100% PALF have been used on cotton machinery system with some machine modifications and produce PALF yarns with favorable tenacity (14.0 g/tex) [4].

A. Jute Spinning System

Blending of PALF and jute fibers yield great quality fiber that best utilized as decorative material [1]. Binary blending between PALF and jute will produce very fine yarn in term of linear density which is seems impossible to achieve with Indian jute alone.

B. Semi-worsted Spinning System

PALF blended with wool yarns were spun by using semi-worsted spinning system with variable blend proportion. Yarns produced from blend proportion 25:75 of PALF:Wool was ideal for carpet face and home furnishing fabrics manufacturing.

C. Flax Spinning System

There is improvement of weight irregularity that resulting in better yarn diameter regularity of PALF spun using flax spinning system (wet) compared to jute spinning system (dry). Table III showed the comparison between PALF yarn spun using jute and flax system.

TABLE III. PALF Spinning on Jute and Flax Spinning System

Properties	PALF yarn	
	Jute System	Flax System
Linear density (tex)	85.10	82.14
Uster fineness (U%)	29.50	27.50
Average diameter (cm)	0.333	0.311
Breaking stress (gm/tex)	17.33	19.81
Breaking strain (%)	8.80	8.20
Packing coefficient	0.65	0.72

D. Cotton Spinning System

The ability of PALF spun on cotton spinning machine was improved after chemical treatment. There are two approaches of spinning PALF using cotton spinning machine that is by binary blending which blend PALF with cotton in variable proportion or using 100% PALF with some modifications on the machine system. There are three main stage of PALF spinning on cotton machinery that is carding, drawing (draw frame), and spinning (spinning frame) [4].

E. Jantra

On the other hand, in Indonesia there is an equipment that have been used to spin short fiber including PALF into yarns. This machine was originally invented for spun silk; yarn made from short-fibered silk and silk waste and then being applied on PALF [5]. This machine is called Jantra and showed in Fig. 2.

Figure 2. *Jantra*

V. Future Work

From the previous study, it has been approved that PALF can be spun into yarns. However, the PALF yarns produced still coarse and still not in line with cotton yarns properties. Before PALF can be spun, there some considerations need to be taken into account. One of them is PALF degumming process. PALF consists about 30% of pectin, pentosan, and lignin that make it steep in nature [4]. Moreover, the remaining resin makes PALF coarser and brittle. The coarsen PALF can be softened by degumming process which can be carried out using acid, alkali, or axines.

After that, PALF need to go through fiber cut and opener system in order to cut the fiber according to its effective length. At the end, only very fine and soft fiber will be selected. The selected fiber is then can be spun by using cotton spinning system with some modifications. Spinning process involves carding, drawing, and ring spinning.

Apart from that, further studies on the effect of fiber properties and linear density on PALF yarn hairiness in spinning system is necessary. There are several parameters that will affect yarn hairiness [6]. The hairiness parameters should be involved for comprehensive yarn hairiness evaluation included (a) total number of hairs per unit yarn length, (b) total length of hairs per unit, (c) the length and number of hairs and longer than or equal to 3mm per unit length.

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Before a comprehensive evaluation of yarn hairiness is done, there is a need on studied of several fiber properties. They are fiber length, uniformity ratio, micronaire, strength, short fiber index, elongation, and trash count. All of these parameters can be tested by using either high volume instruments (HVI) machines, advanced fiber information system (AFIS), or fiber contamination tester (FCT).

VI. Summary

As the industrial importance and plantation area of pineapple increasing, it makes economic and environmental sense to energize the research and development area to enhance PALF productions as well as PALF utilization. Developmental works must be carried out in order to mechanize PALF extraction and PALF treatment to enhance the PALF properties especially wet strength improvement of the PALF. The recent development on PALF showed that PALF will be able to capture significant used among natural fibers but there is a concern on to assure the enough supply in industry. An improvement of the existing process includes machinery evaluation towards up-scaling technology.

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