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PHYSICAL PROPERTIES OF BANANA PSEUDO-STEM WOVEN FABRIC TREATED WITH SOFTENING AGENT

Wan Syazehan Ruznan[1], Suraya Ahmad Suhaimi[1]*, Nor Juliana Mohd Yusof[2],
Nazzuha Pairan[1], Aimi Umairah Mazlan[1], Anis Naziihah Azrain[1], Intan Shahirah Md Rosli[1], Nur Izzati Othman[1]

[1] *School of Industrial Technology, Faculty of Applied Sciences, Universiti Teknologi MARA Negeri Sembilan, 72000 Kuala Pilah, Negeri Sembilan, Malaysia*
[2] *Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*

**Corresponding author: suraya294@uitm.edu.my*

Abstract
Fibres from banana's stem are abundantly available in Malaysia. This study focused on the production of woven fabric from banana pseudo-stem fibres. Yarn made of 100% banana stem and 100% cotton yarn were produced. Two types of retting techniques were conducted, which are water retting and retting using softening agent. The fibres were spun and weaved into plain weave fabric. All specimens were evaluated for yarn twist, yarn evenness, yarn linear density and selected fabric physical properties. The results obtained showed that banana stem fabric treated with softening agent has lower area density and higher thickness. Weft sample retted in softening agent has higher bending length and flexural rigidity than sample retted in water. This might be due to the decrement of yarn's stiffness, which eases the insertion of yarn during shedding process. Weft sample retted in water has lower bending length due to coarser yarn and tends to break easily. It is found that retting banana stem fibres with softening agent affect the yarn linear density, area density, fabric stiffness properties and flexural rigidity of the fabric.

Keywords: banana stem fibre, softening agent, stiffness, woven fabric

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Introduction
Natural fibres have under intensive study worldwide due to their continuous supply, safe handling biodegradability and nontoxicity. They are usually low-cost fibres with low density with high specific properties (Santosha et al., 2018). Known as banana, with a few botanical names i.e. *Musa Paradisiaca, Musa Sapientum, Musa Cavendishii* and *Musa Chinensis* (Sharma, 2013) is cut down approximately 10 million every year to meet the demand in Malaysia (Baharin et al., 2016). Almost every part of the banana plant can produce fibres of various strength and length. Banana pseudo-stem fibres is characterised as bast fibres and is renowned as good source of fibre not only in Malaysia, but also in Philipinnes, Indonesia, India, Nepal, Paraguay and Japan (Ramdhonee and Jeetah, 2017). Almost each and every part of banana plant gives fibres of various strength, colour and long staple length. There is about 14 to 18 sheath layers available in the stem, the outermost for 4- 6 sheaths yield courser fibres, while the next 6-8 sheaths are soft and lustrous fibres, and the rest middle sheaths excluding the innermost 4-6 sheaths yield very soft fibres (Vigneswaran et al., 2015). There are three distinct layers: 1) outer layer including the epidermis, which contain fibres dispersed in a soft tissue matrix, 2) the middle layer, consists of water transporting fibre vascular tissue, and 3) the inner layer, consists of soft, cellular tissue (Vigneswaran et al., 2015). The quantity of fibre in each sheath depends upon its width and its location in the stem as does its quality (Vigneswaran et al., 2015).

The banana pseudo-stem is also used as pulp and paper, fibre for textile products and filler for structural reinforcement in composites material (Subagyo and Chafidz, 2018, Salleh et al., 2015). Banana pseudo-stems fibres used in papers making increase the life span of the paper over 100 years due to the long bast fibres (Bhatnagar et al., 2015). It can also be used to produce valuable documents such as manuscript document preserver (Bhatnagar et al., 2015). It is shown that banana fibre can be used as an excellent reinforcing agent due to its high surface area, unique morphology and mechanical strength, which may be suitable for automotive application (Umachitra et al., 2017.)

Over the years, a lot of research works has been conducted on the utilisation of banana pseudo-stem fibres. Most of the work focused on fabricating biocomposites (Maleque et al., 2007, Sapuan et al., 2007, Venkateshwaran and Elayaperunal, 2010, Jandas et al., 2012). Banana pseudo-stem fibres were usually combined with other materials as matrices, generally to increase the strength of the composite materials. Studies on physical properties of banana stem fibres also found that it has higher moisture content, absorbent and fast release of moisture. It is a strong fibre and has lower strain at break. (Subagyo and Chafidz, 2018). The banana stem fibres are usually coarse after it has been extracted and scraped, making the process of yarn difficult and affect the texture of the woven fabric. Some of the research works conducted highlight commercial softening agent as a chemical retting treatment to improve the hand properties of natural fibres after extraction using sodium hydroxide (NaOH) (Ebisike et al., 2013). The retting procedure is crucial to the process ability of the fibres because alkaline treatment is used for the release of fibres just as it is one of the standard procedures in the pulp and paper industries for lignin removal, lignin can be dissolved in sodium hydroxide (NaOH) solution and the cellulosic fibres can be extracted with relative ease (Ebisike et al., 2013). Bananas fibre extraction could be done in three ways i.e. chemical and mechanical method (Subagyo and Chafidz, 2018). Retting process allow the decomposition of pectin that binds the fibres to the woody inner core of the plant (Ebisike et al., 2013). A research work conducted by Ebisike (2013) showed that fibre from banana stem was successfully extracted using various concentrations of sodium hydroxide i.e. 0.00 M, 0.01 M, 0.05 M and 0.1 M (Ebisike et al., 2013). A study on comparison of extraction methods has also been conducted showing pseudo-stem banana fibres that were chemically and enzyme extracted are finer with rougher surfaces as compared with mechanically extracted (Xu et al., 2015).

This study is focusing on the production of banana stem woven fabric treated with commercial softening agent and water retting to determine the stiffness properties of the woven fabric. In this study, the fibres were obtained by mechanical extraction process, which is the eco-friendliest way to get higher volume of fibres.

Methods

Fibre Extraction

Banana pseudo-stem fibres from '*pisang tanduk*' or plaintain species were chosen for this study. The banana stems were cut into thin pieces. The outer layer of banana stem was discarded and the inner layer of banana stem fibres was used. The banana stems were compressed to remove the water from the stem. The pseudo-stems were then chopped and divided into three sections to make the compression process easier.

Retting Process

Chemical retting was used in this research work. The pseudo-stem layers and 100% cotton yarns were soaked in two different agents i.e. water and commercial softening agent within 24 hours to compare the effectiveness of retting and the effect of stiffness due to different agent. The amount of water is 3500 ml and the amount of softening agent is 100 ml to be diluted in 3400 ml of water.

The banana pseudo-stem fibres were then scraped by using a steel scraper to separate the individual fibre from the lignocellulose layer (Figure 1). Hair dryer was used to dry the fibre prior combing.

Figure 1. Scraping process of banana pseudo-stem fibres

After the lignocellulose layers were removed, the fibres were combed to make the fibres parallel and to remove the impurities. This process was done by using a very fine comb to get a fine parallel fibre (Figure 2).

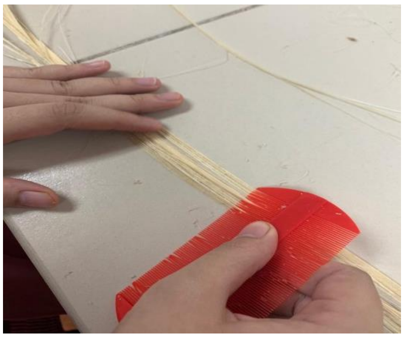

Figure 2. The combing process of banana pseudo-stem fibre

Using electronic hand spinning machine (Figure 3), approximately in every 1 metre of fibre, the weight must be 0.1 gram to ensure the linear density of the yarn produced is consistent. The fibres were then drafted and twisted before weaving process.

Figure 3. Electronic hand spinning machine

Process of weaving the spun yarn was done using mini table loom with plain weave structure. Meanwhile, 100% banana spun yarn was used for weft direction, and 100% cotton yarn for warp direction.

Figure 4. Weaving process using hand loom

Yarn Characterisation

There was selected yarn testing performed in this study i.e. area density, yarn linear density, yarn twist and yarn evenness using cut-and-weigh method. Fabric physical properties i.e. fabric weight, fabric thickness and fabric stiffness test were performed to analyse stiffness properties of different fabric produced.

The amount of twist in single yarn is counted based on of twist per inch (tpi) or per cm (tpcm). This test is to determine the amount of twist in a certain length of yarn. The untwist method was used in this study. The equipment used was Frank Twist Tester and the standard method is ASTM D1423-02/2008. Fabric thickness test was conducted by using the thickness gauge. A thickness gauge has a broad anvil upon, which a presser foot is pressed by a spring. The fabric sample was placed on the anvil and the presser foot is lowered very slowly on to the sample.

Fabric Stiffness Test

This test measures the bending length, flexural rigidity of a fabric that is related to fabric weight, handle and thickness. SDL fabric stiffness tester was used and the test is in accordance with ASTM D1388-18. Each sample was the same size as the template (6-inch x 1 inch), where the samples were placed on the sliding board with the edge of sample in line with the dotted point. The template was placed on top of the sample and the template was slid until the edge is seen touching the single black line seen in the mirror.

Result and Discussion

Linear Density

Linear density for 100% cotton yarn shows higher yarn Tex after water retting i.e. 245 Tex, as compared to yarn retted with softening agent, which is 239 Tex. The same scenario was observed for yarns made of 100% banana pseudo-stem where with water retting, the size is 199Tex and 126 Tex for softening agent retting. A reduction of size ~2.4% for 100% cotton yarn and ~37% for 100% banana pseudo-stem were recorded (Figure 5), which might be due to the interaction of the softening agent and lignocellulose that have been removed during the retting process. On the other hand, the use of water in retting process might only have loosened the fibres from other components without reducing the amount of lignin that attached to the fibres (Ebisike et al., 2013).

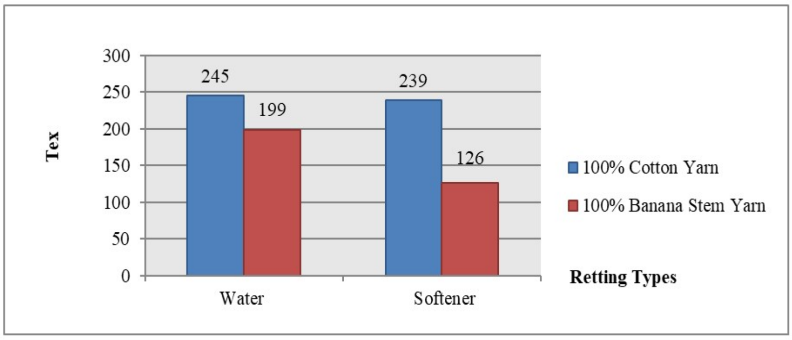

Figure 5. Linear Density

Yarn Twist

The result of yarn twist in Figure 6 showed that treated yarn and untreated yarn have slightly different number of twists per meter. This is due to the increase or decrease in twist value depends on the tension put to the yarns during spinning process.

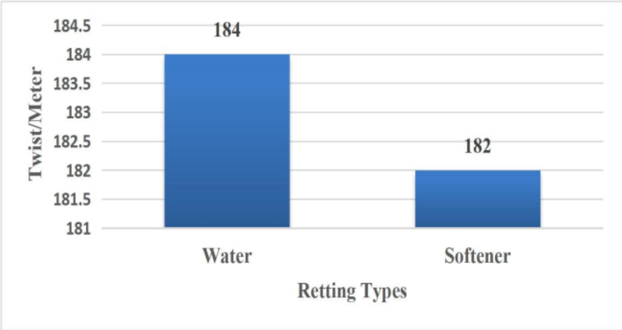

Figure 6. Yarn twist

Fabric Area Density

The dimension of woven fabric produced was 22.5 cm length and 17 cm width, with 18 warps/inch and 9 wefts/inch for fibres retted with water. Meanwhile, the density for fibre retted with softening agent is 20 warps/inch and 11 wefts/inch. Figure 7 shows the results of fabric area density. Area density of sample with water retting is 373.15 Tex, while the area density of sample retted with softening agent is 342.72 Tex. It shown that sample with water retting is higher than sample retted with softening agent, which might be due to the losses of lignin on the fibre surfaces and make the fibre finer after retting. During weaving process, the wefts yarns inserted during picking motions might be higher due to the finer yarn size.

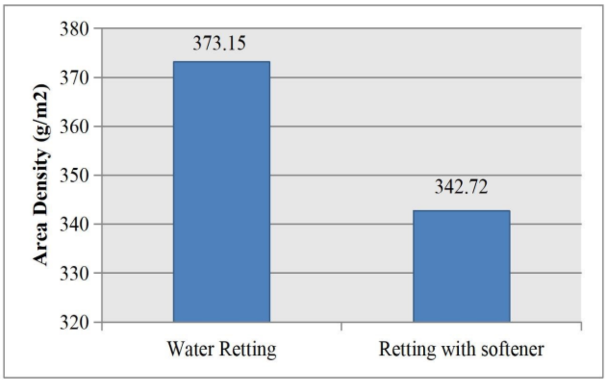

Figure 7. Area density

Thickness

Figure 8 shows the result of fabric thickness, where retting with softening agent gives higher thickness (1.55 mm) than water retting (1.48 mm), which might be due to the increment of yarn thickness for fibres retted with softening agent. During retting process, the fibres might have been coated with the softening agent molecule. Despite softening the fibre and making it feel smooth, soft and flexible by internal lubrication of the fibres, the softening agent will also increase the thickness of the individual fibre (Ruznan et al., 2012).

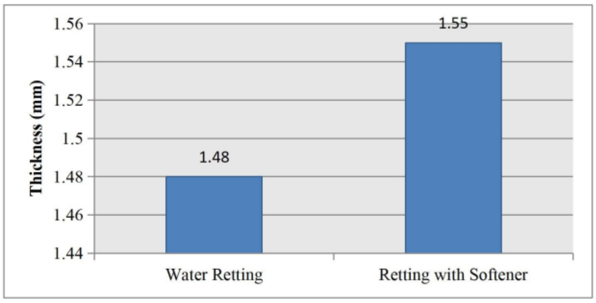

Figure 8. Fabric thickness

Fabric Stiffness

Bending length of warp sample retted in water is 2.27 cms, while 1.22 cms for weft sample (Figure 9). Warp sample has higher bending length than weft sample due to different fibre types i.e. 100% cotton for warp and 100% banana pseudo-stem for weft. Meanwhile, the bending length of warp sample retted in softening agent is 2.07 cms while for weft sample is 2.52 cms. Weft sample retted in softening agent has higher bending length due to the softness and flexibility (Ruznan et al., 2012), hence more yarn interlacement can be done during the weaving process. Weft sample retted in water has lower bending length due to coarser yarn and it tends to break easily, making lesser yarn interlacement could be done during weaving.

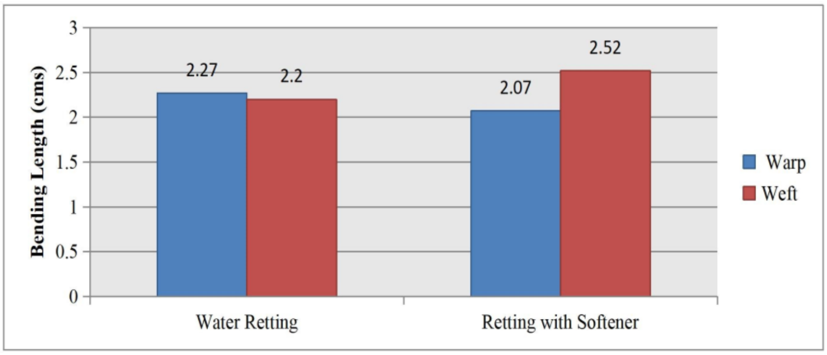

Figure 9. Bending length for stiffness test

Flexural Rigidity

The weft sample retted in softening agent has higher flexural rigidity than sample retted in water, approximately 22% i.e. 86.36 mg.cm (Figure 10). This might be due to more interlacement of yarn was inserted during weaving processes because of the softness and flexibility of the individual fibre.

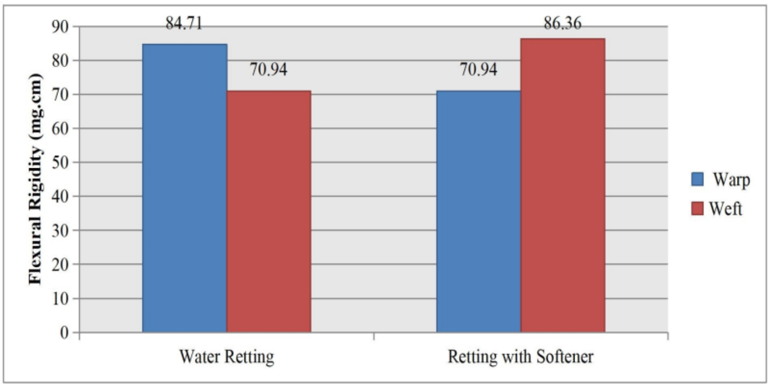

Figure 10. Flexural rigidity for stiffness test

Conclusion

The stiffness of banana stem woven fabric treated with commercial softening agent and water retting was analysed. The stiffness characteristic is distinctive for warp and weft samples due to different types of fibres used. Weft samples retted in softening agent has higher bending length and flexural rigidity than samples retted in water. Samples retted in softening agent ease the spinning and weaving process where the yarns become soft and more flexible. The amount of yarns increased during interlacement; hence the fabric is more compact. It can be concluded that retting banana pseudo-stem fibres with softening agent affect the yarn linear density, area density, fabric stiffness and flexural rigidity of the fabric.

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