Characteristics and Properties of Paper Mulberry Yarns

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Abstract

The objective of this research was to determine the characteristics and physical properties of paper mulberry yarns spun by different methods. The materials used for this study were the inner barks of paper mulberry trees (Broussonetia papyrifera (L.) Vent.), between 6 to 12 months old. The paper mulberry yarns were spun by the modified hemp spinning method using 2, 4 and 6 mm strips and the modified cotton spinning method using 3.5, 5 and 6.5 cm fibers. The yarns produced were tested for physical properties according to the American Society of Testing Materials (ASTM) standards. It was found that the modified hemp spinning methods produced much smoother yarns, but they were still uneven in texture and classified as grade C. In contrast, the modified cotton spinning methods produced fuzzy and rough yarns, more uneven in texture and classified as below grade D. The paper mulberry yarns spun by different methods statistically had different yarn count, yarn twist, yarn breaking strength and yarn elongation at the .01 level. The yarn spun by the modified hemp spinning method using 6 mm strips had the highest yarn count, breaking strength and elongation, while the yarn spun by the modified cotton spinning method using 3.5 cm fibers had the highest yarn twist.

Keywords: Paper mulberry, Fiber, Yarn, Physical properties, Modified hemp spinning, Modified cotton spinning

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1. Introduction

Paper mulberry (Broussonetia papyrifera (L.) Vent.) is a traditional ornamental deciduous large shrub or tree with a round crown up to 50 feet (15 m) in height and boles up to 2 feet (0.6 m) in diameter. Paper mulberry often appears as shrub-forming thickets from root sprouts [1]. The twigs are hairy reddish brown, and the bark is tan and smooth to moderately furrowed. The wood is soft and brittle with conical buds [2]. The bast from paper mulberry is a widely applied traditional raw material for small scale paper mills in Southeast Asia, mainly Thailand, Myanmar, Vietnam, South China, Taiwan, Korea and Japan [3]. It is the main raw material for handmade paper in Thailand [4]. Saa, or the popular name given to the paper mulberry tree, is a coarse, strong, rigid material and has a natural based fiber. Paper mulberry (kouzo) has also been used to make Japanese paper, but cultivation of the paper mulberry has been decreasing. Likewise, paper mulberry can be used for producing paper yarn [5]. The paper mulberry bark should be an excellent raw material for long-stable fiber [6]. The fiber is unique, long and very strong. It is the best choice for many to be used for making high quality paper. The treatment of paper mulberry bark, with crude pectinase, suggests the application of pectinases in producing high quality fiber [7]. The paper mulberry branch bark is a potential source of pectin with different degrees of esterification [8]. In primary study [9], the characteristics and physical properties of the paper mulberry fiber were found as follows:

1) The fibers were in clusters with an average diameter of 10 micrometers and had rounded cross-section with lumen and uneven texture and node.

2) The average length of single fibers was 10.20 mm. and therefore classified as short fiber, while that of the bundle fibers was 42.27 mm and classified as extra-long fiber. The average density of single fibers was 0.95 tex, whereas that of the bundle fibers was 13.04 tex. The average moisture content of the single fibers was 8.14% and that of the bundle fibers was 10.66%. The average tenacity of the single fibers was 4.85 cN/tex and that of the bundle fibers was 15.90 cN/tex. The average elongation of the single fibers was 4.50% and that of the bundle fibers was 11.21%. In this study, the paper mulberry yarns

were experimentally produced and the characteristics and physical properties of the yarns were examined, to educate and encourage the utilization of paper mulberry fiber for an environmental friendly and sustainable use for natural textiles.

2. Objective

To determine the characteristics and physical properties of the paper mulberry yarns spun by different methods

3. Research methodology

3.1 Materials

The materials used for this study were eighteen kilograms of paper mulberry (Broussonetia papyrifera (L.) Vent.) inner barks, between 6 and 12 months old, from the Mea Fah Luang Foundation, in Chiangrai province (Figure 1).

Figure 1 The paper mulberry barks used for this study

3.2 Methods

3.2.1 Preparation of the Paper Mulberry Barks

The preparation of the paper mulberry barks was carried out in three steps.

1) The cortex or barks were removed by hand decortication.

2) The cortex was scraped to remove most of the outer barks from the woody stem, the parenchyma in the bast layer and some of the gums and pectins.

3) The barks were washed 2 to 3 times in water; then the barks were completely dried out.

3.2.2 Preparation of the paper mulberry fibers for yarn spinning

The inner barks were divided into two parts. Both were used for the developed two different hand spinning methods: the modified hemp spinning method and the modified cotton spinning method.

1) Preparation of the paper mulberry bundle fibers for the modified hemp spinning method: The inner barks were separated into strips in three width sizes; 2 mm, 4 mm and 6 mm, as shown in Figure 2.

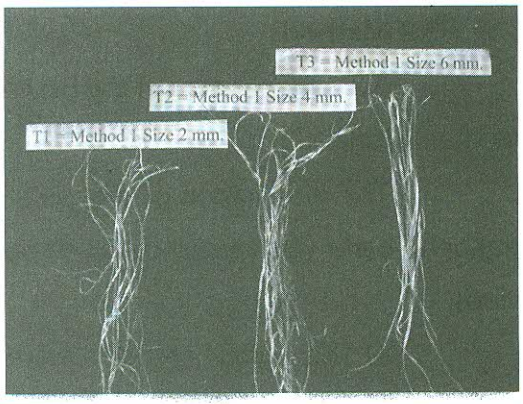


Figure 2 The paper mulberry strips in three sizes width for the modified hemp spinning method

2) Preparation of the paper mulberry fibers for the modified cotton spinning method: First the inner barks in three sizes length; 3.5 cm, 5 cm and 6.5 cm, were cut off and separated into bundle fibers (approximately 13 tex) by hand, as shown in Figure 3.

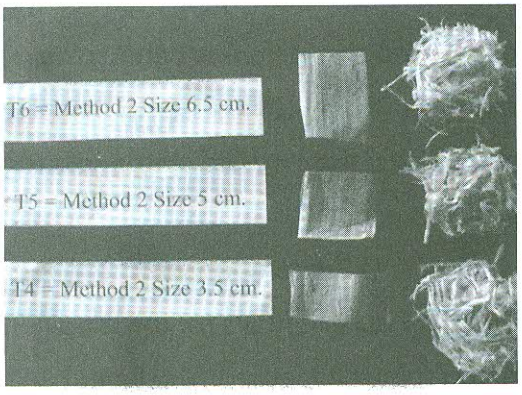


Figure 3 The paper mulberry fibers in three sizes length for the modified cotton spinning method

3.2.3 Spinning of the Paper Mulberry Yarns

1) The modified hemp spinning method (MH):

This spinning method was developed by modifying the hemp spinning method widely used in the Northern part of Thailand. This method was tested using three sizes of paper mulberry bark strips: 2 mm, 4 mm, and 6 mm. The process consisted of four steps as follows:

a) The bark strips were pounded for three hours to further soften and affine the strips and remove lignin.

b) The bark strips were joined to make continuous fiber strips using the Northern Thai traditional hand method for hemp (twisting).

c) The fiber strips were hand spun to make continuous yarn.

d) The yarn was boiled to remove lignin, finish and soften the yarn.

2) The modified cotton spinning method (MC):

This spinning method was modified from the traditional hand spinning method of cotton yarn, which is widely used in the Northeast of Thailand. This method was tested using three fiber

lengths: 3.5 cm, 5 cm and 6.5 cm. The process consisted of three steps as follows:

a) Fibers were cleaned or scotched in water to soften and increase the fineness of the bundle fibers.

b) Bundle fibers were rolled to make a long strand of a sliver using the Northeast Thai traditional hand method for cotton.

c) Fibers were spun to form a yarn by a combination of drawing or drafting and twisting the prepared strands of fiber. A spinning wheel was used to mechanize the spinning process, and the rollers were used to draft the fiber bundle and rotate the spindle.

3.2.4 Testing of the Paper Mulberry Yarns

The characteristics and physical properties of the paper mulberry yarns were determined according to the ASTM standard testing methods [10] as follows:

1) Yarn count was tested according to the ASTM D1059-01 Standard Test Method for Yarn Number Based Short-Length Specimens.

2) Yarn twist was tested according to the ASTM D1423 - 02 Standard Test Method for Twist in Yarn by Direct-Counting.

3) Yarn appearance was determined using an electron microscope and according to the ASTM D2255-02 Standard Test Method for Grading Spun Yarns for Appearance.

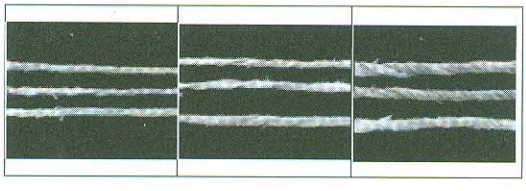
4) Yarn breaking strength and elongation were tested using an Instron Tensile Tester according to the ASTM D 2256-02 Standard Test Method for Tensile Properties of Yarns by the Single-Strand Method.

4. Research findings and discussions

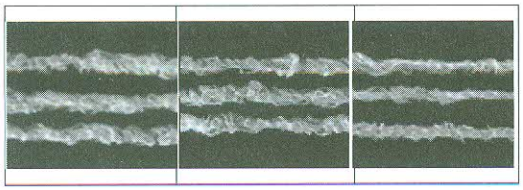
4.1 The Characteristics of the Paper Mulberry Yarns

Six yarns obtained from two spinning methods were investigated in two aspects of characteristics as follows:

4.1.1 The longitudinal view of the paper mulberry yarns



(a) (b) (c)

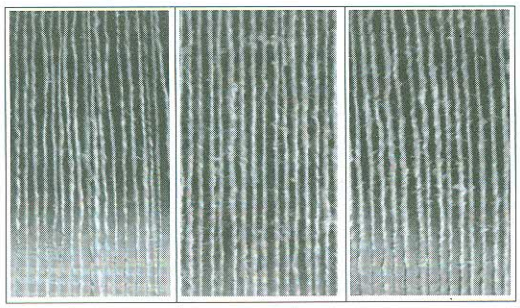


(d) (e) (f)

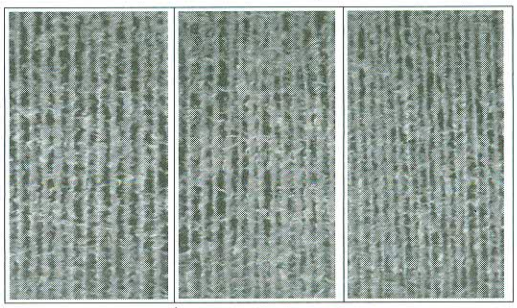
Figure 4 Longitudinal view of the yarn spun by different methods: (a) modified hemp (MH) with 2 mm strips, (b) modified hemp (MH) with 4 mm strips, (c) modified hemp (MH) with 6 mm strips, (d) modified cotton (MC) with 3.5 cm fibers, (e) modified cotton (MC) with 5 cm fibers, and (f) modified cotton (MC) with 6.5 cm fibers.

Figure 4 shows that the MH method could produce much smoother yarns than the MC method, therefore, the MH method should be more suitable for producing warp yarns. In contrast, the yarns produced from the MC method had a more fuzzy and rough texture. They looked like novelty yarns, therefore, the MC method should be more suitable for producing filling yarns.

4.1.2 The evenness of the paper mulberry yarn



(a) (b) (c)



(d) (e) (f)

Figure 5 The evenness of the paper mulberry yarns spun by different methods: (a) modified hemp (MH) with 2 mm strips, (b) modified hemp (MH) with 4 mm strips, (c) modified hemp (MH) with 6 mm strips, (d) modified cotton (MC) with 3.5 cm fibers, (e) modified cotton (MC) with 5 cm fibers and (f) modified cotton (MC) with 6.5 cm fibers.

Figure 5 shows that the paper mulberry yarns spun by the MH methods, (a), (b) and (c) were uneven in texture, which could be classified as grade C level, whereas the yarns spun by the MC methods, (d), (e) and (f) were more fuzzy and uneven in texture. As a result, they were classified as below grade D level. The paper mulberry yarns had some texture. Therefore, it might be suitable for household fabrics.

4.2 Physical Properties of the Paper Mulberry Yarns

The study investigated the following aspects of the yarn's physical properties:

yarn count, yarn twist, yarn breaking strength and elongation. The ASTM standard test methods were used. The results are shown in Table 1 - 4 as follows:

4.2.1 Yarn count

Table 1 Means of yarn count of the paper mulberry yarns produced by different spinning methods.

Yarn Spinning Methods	Yarn Count (tex)	
	$\overline{X}$	S.D.
MH with 6 mm strips	1683.88[a]	13.44
MH with 4 mm strips	1310.14[b]	10.52
MC with 3.5 cm fibers	1271.70[bc]	4.96
MC with 5 cm fibers	1150.68[c]	16.90
MC with 6.5 cm fibers	1022.78[d]	18.12
MH with 2 mm strips	963.48[d]	14.00

Different alphabets indicate statistical difference at the .05 level

From Table 1, the data show that the yarn spun by MH method with 6 mm strips was the heaviest followed by the yarn spun by the MH method with 4 mm strips. Meanwhile, the yarn spun by the MH method with 2 mm strips was the smallest. All of the paper mulberry yarns produced, however, were classified as heavy yarns [11]. Therefore, those yarns can be used for home textiles such as floor covering fabrics. In a further study, it would be interesting to experiment with smaller yarns. The six different methods tended to produce yarns with different counts. Variation analysis of the means yarn count revealed that different spinning methods resulted in different yarn count at the .01 level.

The result of Least Significant Ranges (LSR) analysis to measure the mean difference of yarn count of the yarns spun by different methods showed that the count of the yarn spun by the MH method with 6 mm strips was statistically higher than those of the others at the .05 level. The count of the yarn spun by the MH method with 4 mm strips was statistically higher than those of the yarns spun by the MC methods with 5 and 6.5 cm fibers and that of the yarn spun by the MH method with 2 mm strips at the .05 level. The count of the yarns spun by the MC methods with 3.5 cm and 5 cm fibers were statistically higher than that of the yarn spun by the MC method with 6.5 cm fibers and that of the yarn spun by the MH method with 2 mm strips at the .05 level.

4.2.2 Yarn twist

Table 2 Means of yarn twist of the paper mulberry yarns produced by different spinning methods

Yarn Spinning Methods	Yarn Twist (turns/inch)	
	$\overline{X}$	S.D.
MC with 3.5 cm fibers	10.80[a]	.84
MC with 5 cm fibers	9.80[b]	.84
MC with 6.5 cm fibers	8.80[c]	.45
MH with 2 mm strips	5.60[d]	.89
MH with 6 mm strips	5.00[d]	.71
MH with 4 mm strips	4.60[d]	.55

Different alphabets indicate statistical difference at the .05 level

From Table 2, the data show that the yarn spun by the MC method with 3.5 cm fibers had the highest yarn twist followed by the yarn spun by the MC method with 5 cm fibers. In contrast, the yarn spun by the MH method with 4 mm strips had the lowest yarn twist. All yarns were classified as low twist ones. Therefore they should be used for home textiles such as certain and upholstery fabric. The six different methods tended to produce yarns with different twist. Variation analysis of the means yarn twist revealed that different spinning methods resulted in different yarn twist at the .01 level.

The result of Least Significant Ranges (LSR) analysis to measure the mean difference of yarn twist of the yarns spun by different methods indicated that the MC method with 3.5 cm fibers produced the highest yarn twist and was statistically higher than the others at the .05 level. The twist of the yarn spun by the MC method with 5 cm fibers was statistically higher than that of the yarn spun by the MC method with 6.5 cm fibers, and those of the yarns spun by the MH methods with 2 mm strips, 6 mm strips and 4 mm strips at the .05 level. The twist of the yarn spun by the MC method with 6.5 cm fibers was statistically higher than those of the yarns spun by the MH methods with 2 mm strips, 6 mm strips and 4 mm strips at the .05 level.

4.2.3 Yarn breaking strength

Table 3 Means of yarn breaking strength of the paper mulberry yarns produced by different spinning methods

Yarn Spinning Methods	Yarn Breaking Strength (cN/tex)	
	$\overline{X}$	S.D.
MH with 6 mm strips	551.06[a]	12.67
MH with 4 mm strips	352.71[b]	5.52
MH with 2 mm strips	264.22[c]	17.40
MC with 5 cm fibers	83.44[d]	11.64
MC with 6.5 cm fibers	66.39[de]	8.62
MC with 3.5 cm fibers	36.14[e]	6.90

Different alphabets indicate statistical difference at the .05

From Table 3, the data show that the paper mulberry yarn spun by the MH method with 6 mm strips had the highest breaking strength followed by the yarn spun by the MH method with 4 mm strips. On the other hand, the paper mulberry yarn spun by the MC method with 3.5 cm fibers had the lowest breaking strength. The yarns spun by the MH methods had higher breaking strength than the yarns spun by the MC methods because the MH method utilized long fiber spinning, whereas the MC method utilized short fiber spinning. These different spinning methods resulted in different breaking strength of the yarn. Therefore, those yarns can be used for technical textiles such as reinforce fabric for construction and home textiles such as floor covering and upholstery fabrics. On the other hand, the paper mulberry yarns spun by the MC methods had low breaking strength, therefore they should be used for home textiles. The six different methods tended to produce yarns with different breaking strength. Variation analysis of the means yarn breaking strength revealed that different spinning methods resulted in different yarn breaking strength at the .01 level.

The result of Least Significant Ranges (LSR) analysis to measure the mean difference of breaking strength of the yarns spun by different methods revealed that breaking strength of the yarn spun by the MH method with 6 mm strips was statistically higher than the others at the .05 level. The breaking strength of the yarn spun by the MH method with 4 mm strips was statistically higher than those of the yarns spun by the MH method with 2 mm strips, and the MC methods with 5 cm fibers, 6.5 cm fibers and 3.5 cm fibers at the .05 level. The breaking strength of the yarns spun by the MH method with 2 mm strips was statistically higher than those of the yarns spun by the MC methods with 5 cm fibers, 6.5 cm fibers and 3.5 cm fibers at the .05 level. The yarn spun by the MC method with 5 cm fibers was statistically higher than that of the yarn spun by the MC methods with 3.5 cm fibers at the .05 level.

4.2.4 Yarn elongation

Table 4 Means of yarn elongation of the paper mulberry yarns spun by different spinning methods.

Yarn Spinning Methods	Yarn Elongation (%)	
	$\overline{X}$	S.D.
MH with 6 mm strips	25.36[a]	.40
MC with 5 cm fibers	19.41[b]	.70
MC with 6.5 cm fibers	17.80[c]	.91
MH with 4 mm strips	17.07[c]	.89
MC with 3.5 cm fibers	14.05[d]	.91
MH with 2 mm strips	13.33[d]	.63

Different alphabets indicate statistical difference at the .05 level

From Table 4, the data show that the yarn spun by the MH method with 6 mm strips had the highest elongation followed by the yarn spun by the MC method with 5 cm fibers. Meanwhile, the yarn spun by the MH method with 2 mm strips had the lowest elongation. In terms of yarn elongation. These yarns should be used for home textiles such as interior decoration and upholstery fabrics. The jute fibers is also a bast fiber. Their properties are hairy and generally rough. It is used for making gunny bags and cords [12]. The six different methods tended to produce yarns with different elongation. Variation analysis of the means yarn elongation revealed that different spinning methods resulted in different yarn elongation at the .01 level. The result of Least Significant Ranges (LSR) analysis to measure the mean difference of yarn elongation of the yarns spun by different methods revealed that elongation of the yarn spun by the MH method with 6 mm strips was statistically higher than those of the others at the .05 level. The elongation of the yarn spun by the MC method with 5 cm fibers was statistically higher than those of the yarns spun by the MC method with 6.5 cm fibers, the MH method with 4 mm strips, the MC method with 3.5 cm fibers and the MH method with 2 mm strips at the .05 level. The elongation of the yarns spun by the MC method with 6.5 cm fibers and the MH method with 4 mm strips were statistically higher than those of the yarns spun by the MC method with 3.5 cm fibers and the MH method with 2 mm strips at the .05 level.

5. Conclusions

In this research, it was found that the paper mulberry fibers could be spun into yarns by the two methods developed: the modified hemp spinning method (MH) and the modified cotton

spinning method (MC). As a result, the MH methods could produce much smoother yarns than the MC methods. In contrast, the yarns spun by the MC methods were more fuzzy and rough. Most of the MH methods produced the yarns with higher breaking strength while the yarns spun by the MC methods had higher yarn twist. Moreover, the yarns spun by different methods statistically had different yarn count, yarn twist, yarn breaking strength and yarn elongation at the .01 level. From this research, it could be concluded that more value can be added to paper mulberry production. Consequently, it could be concluded that based on the characteristics and properties of the produced paper mulberry yarns, they could be used for producing the home textile and technical textile products.

6. Recommendations

The paper mulberry fiber could be spun into yarns by hand spinning methods that were fuzzy and heavy in size. They should be used for home textiles. Therefore, in a further study, it would be interesting to investigate the yarn spinning with a spinning machine used in the textile industry.

The materials used for this study were the inner barks of paper mulberry between 6 to 12 months old. The yarns obtained were coarse and strong. Therefore, in a further study, it would be interesting to study the younger paper mulberry tree in order to make finer and softer yarns.

7. Acknowledgment

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