Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Development of Nipa palm fibers for textiles

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ABSTRACT

The purpose of this research was to study the physical properties of Nipa palm fibers and test the properties of the fibers obtained from the yarn-spinning process. In visiting community groups that produced Nipa palm products in many provinces in Thailand, it was found that the interesting part of Nipa palms that could be brought to develop, build a career, and add value to this plant was Nipa palm fibers, which are tough, strong, and suitable for making wicker products. Interestingly, Kan Mhong Jak (stalks of empty Nipa palm bunches) could be developed into fabrics for use in the design of various products. Additionally, the Nipa palm fibers were mixed with polyester fibers in two different proportions. They were then tested until getting suitable for weaving into the fabrics. The obtained woven fabrics were beautiful, strong, and suitable for further development and creation of other textile products. This can add value to the Nipa palm, a plan that occurs naturally in the community to maximize its benefits and become more well-known.

Keywords: Development, Nipa palm fibers, Textiles
Article type: Research Article.

INTRODUCTION

The Nipa palm, also known as *Nypa fruticans* (scientific name), is a palm tree. It grows in freshwater, brackish water, or saltwater. Thai people have known Nipa palms since ancient times, and there has been wisdom in utilizing them for a long time from their ancestors. It is a native plant that does not need to be taken care of as much as other economically important crops. In addition, it can grow and reproduce naturally and quickly. It is the only type of palm plant in mangrove forests commonly found in South Asia and Southeast Asia. It usually grows into a large grove and grows well in muddy soil in mangrove forests or along canals where trees provide shade in coastal areas. Currently, Nipa palms grow in Sri Lanka, Thailand, Myanmar, Indonesia, Papua New Guinea, the Solomon Islands, the Philippines, and the Ryukyu Islands. In Japan, there are some Nipa palms. In addition, there are Nipa palms in South Queensland, Northern Australia. In Thailand, the benefits of Nipa palms have been known for a long time. For example, the leaves are used to weave into a basket, sewn together to make roofs for the house, and used as a raw material for tobacco smoking. Additionally, Nipa palms can be used to produce Nipa palm sugar. They can also be used to make a container for collecting water in the household called "Mah Jak" and a whip to ward off mosquitoes from the bunches of the Nipa palms called "Mhong Jak" (Foundation Encyclopedia of Thai Culture 1999). Since many benefits and interests of Nipa palms are with the community, and they have been used for a long time, several studies have been conducted to develop the use of Nipa palms by bringing different parts of this plant to test scientific techniques from experts in the public and private sectors. This is in line with the current global trend in which many countries are increasingly interested in products made from natural materials. The Nipa palm fiber products have gained significant attention in recent years for their potential uses in various industries. The fibers are processed to remove impurities and are then used to create products such as mats, baskets, ropes, and even clothing. One of the primary benefits of using Nipa palm fiber products is that they are sustainable and eco-friendly. The Nipa palm tree is a fast-growing plant that requires minimal maintenance and can be harvested multiple times a year. Furthermore, the process

Caspian Journal of Environmental Sciences, Vol. 21 No. 4 pp. 841-852 Received: May 16, 2023 Revised: Aug. 02, 2023 Accepted: Sep. 13, 2023
DOI: 10.22124/CJES.2023.7133

Publisher: University of Guilan,

of extracting the fibers does not require any chemicals, and the leftover material can be used as compost or animal feed. In addition to their sustainability, the Nipa palm fiber products are also durable and resistant to water and pests. This makes them ideal for use in coastal areas where traditional materials such as wood or metal can quickly deteriorate due to exposure to saltwater and humidity. These products have a wide range of potential uses. In the construction industry, they can be used to create roofing materials, insulation, and structural elements. In the fashion industry, designers have experimented using Nipa palm fiber to create clothing and accessories. In addition, these fibers can be used in the production of paper, packaging materials, and biofuels. As the demand for sustainable and eco-friendly products continues to grow, these products represent a promising solution. Owing to their durability, versatility, and eco-friendliness, they have the potential to revolutionize various industries and pave the way for a more sustainable future. From research studies related to the use and development of plant fibers, it was found that fibers from many plants were studied and developed to be used for weaving into various fabrics, such as products made from banana fibers, textile products made from bamboo fibers, and textile products made from lemongrass fibers (Ananwarapong 2018). In addition, there are products made from stalks of empty Nipa palm bunches in the weaving process (Janyatham 2012), and the textile and garment industry develop and uses fibers mixed with Thai rice straw (Cholsakorn 2015). Moreover, water hyacinth fibers have been developed to meet the lifestyle requirements of the eco-friendly market for commercialization (Phuttachot 2019). Textiles and clothing are considered large manufacturing industries with interconnected production structures. It consists of various subindustries involved in the production process. This is from the beginning of the upstream industry, which includes fiber production and spinning. Subsequently, the resulting products will be sent to the midstream industry, namely weaving, knitting, and non-woven fabrics. Finally, it is the downstream industry that brings raw materials obtained from the midstream industry to design, create value, and add value to ready-made garments or other textile products for the benefit of use. The method for utilizing improved plant fibers is to use quality fibers to produce yarns and woven fabrics for different designs and creativity, such as fashion clothing and home textile products. This includes developing textile products with special features and technical textiles (Chonlakup *et al.* 2009). Using natural fibers to produce environmentally friendly textiles is the direction of textile product development, which has increased the strength of textile and fashion products by focusing on the unique properties of natural fibers. This can create a variety of values and differentiations in textiles. Studies on the development of products made from natural fibers are crucial. They should focus on studying and developing the production of textile fibers by focusing on the unique properties of natural fibers, especially Nipa palm fibers. This can diversify the value and differentiation of textile products from the beginning to the end of processes and from experiment and testing to production technology with industrial machines. In the present study, information was obtained from experts in fabric production and fiber development, manufacturers, fiber development institutes, and educational institutions in the field of fabric and design. Therefore, researchers were interested in developing Nipa palm fibers for textiles under the research objectives below. Research objectives were (i) to study the physical properties of Nipa palm fibers; and (ii) to test the properties of these fibers obtained from the yarn spinning process.

MATERIALS AND METHODS

According to the research objectives of this study, the researchers divided the research procedure into two steps: Step 1 was to study the physical properties of Nipa palm fibers in order to be analyzed, starting from surveying the area of Nipa palms to study the process of sorting and testing different parts of the Nipa palms to obtain the fibers that had the best properties in the yarn spinning process. Step 2 involved testing the properties of the Nipa palm fibers obtained from the yarn-spinning process. Further details are discussed below.

Step 1: Studying the physical properties of Nipa palm fibers

In this study, the physical properties of five parts of Nipa palms were studied for further development. They were as follows: (i) Nipa palm leaves; (ii) Nipa palm bunches; (iii) stalks of empty Nipa palm bunches; (iv) Nipa palm stalks; and (v) Nipa palm trunks. Parts of the Nipa palms are shown in Fig. 1. To understand this more clearly, it is crucial to describe the main parts of the nipa palms used in this study. First, Nipa palm leaves include a collection of individual, feathery leaves, approximately 3-9 m long, split around from the stem. In one stem, there were approximately 4-8 leaves. Leafstalks look plump, called Sapok Jak (i.e., Nipa palm trunks). In particular, the base of the leafstalk, called Kan Mhong Jak (stalks of empty Nipa palm bunches), is believed to be the source of nectar production and storage from Nipa palms. The leafstalk consists of approximately 30-40 leaflets called Tang Jak. The leaflets are slender and long. They look like coconut leaves, but the leaf size is wider, approximately 1-1.5 m long. The old leaves will discard the young ones, leaving only the leafstalks until they wither and gradually break off, leaving the appearance of broken marks on the trunks. The Nipa palm stalk is an underground rhizome, often called Hin Jak, that emerges above the soil. The stems were contiguous within the clusters. It looks fat, short, flat, and split into two prongs. The pulp of the stem and the base of the leaf stalk had an air hole. When fully grown, they have a height of approximately 5-8 m. New stems may arise from new tillering or new seeds that are born close to old ones, which are tightly stacked. Nipa palm fruits are tightly packed together at the end of the flower stalk, known as Mhong Jak (i.e., Nipa palm bunches). Each bunch consisted of approximately 50-120 fruits. The fruit was large at the fruit pole and small at the end of the fruit, 10-12 cm long, 6-8 mm in diameter, with a short spike at the base. Each bunch consists of 15-20 fruits. The fruit has a triangular shape. Its peel is thick, and its color is dark brown or reddish-brown. One fruit had one seed next to the fruit shell, which consisted of white flesh. In addition, a hollow and water can be found while the fruit is still immature. This is a suitable time for eating. However, if the seeds are very old, they will have a hard texture, and the whole seed will be sticky. It appeared to be a mature sugar palm. However, it is not popular. In addition, they fall to the ground or float with the current until the water level recedes, sinking into the mud until they are born again (Bamrungrak & Wattanatchariya 2001). Fig. 1 shows parts of the Nipa palms.

1) Nipa palm leaves 2) Nipa palm bunches 3) stalks of empty Nipa palm bunches

4) Nipa palm stalks 5) Nipa palm trunks

Fig. 1. Parts of the Nipa palms.

According to Fig. 1, all five parts of Nipa palms were brought into the process of separating the fibers components as follows.

Part 1. Nipa palm leaves

There are three steps in making the fibers: cutting, hitting, and tearing. The results showed that the obtained fibers were small, thin, and inseparable from the bark of the green leaf. It was thin, easily torn, not sticky, and had few fibers. The leaves took a long time to tear the fibers. The figure below shows how to separate the fibers from the nipa palm leaves.

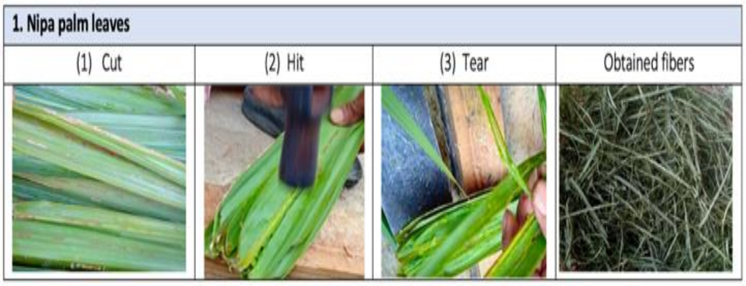


Fig. 2. How to separate the fibers from Nipa palm leaves.

Part 2. Nipa palm bunches

There are four steps for making fibers: cutting, cracking the shell, hitting, and tearing. The obtained fibers were tough and thick, and the texture of the shell was mixed with the fiber. This makes the fibers dark. Each bunch had more than 40 fruits, depending on the size of the bunch. Following this procedure, a large number of fibers were obtained. The length of the fibers was approximately 6.5-7.5 cm in length/fruit. Fig. 3 shows how to separate the fibers from the Nipa palm bunches.

Fig. 3. How to separate the fibers from Nipa palm bunches.

Part 3. Kan Mhong Jak (i.e., stalks of empty Nipa palm bunches)

There are four steps for making fibers: cutting, peeling, hitting, and carding. The result was that this part was fibrous. The obtained fibers were long and uniformly thick. However, it took less time to complete the task. The fibers were tough and straight, creamy white. When it was dry, it turned light brown and stickier. Fig. 4 shows how to separate the fibers from the stalks of the empty Nipa palm bunches.

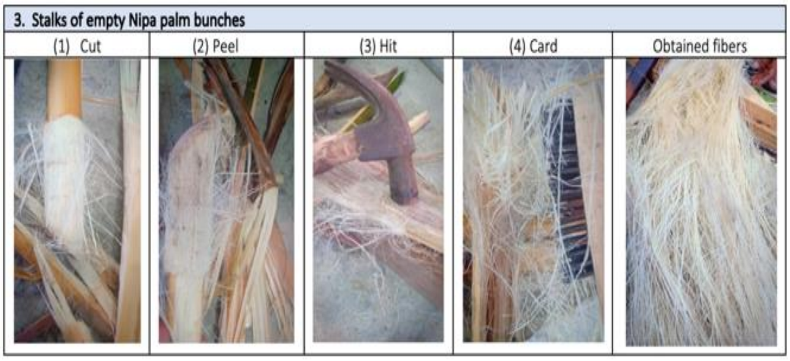


Fig. 4. How to separate the fibers from stalks of empty Nipa palm bunches.

Part 4. Nipa palm stalks

There are four steps for making fibers: cutting, peeling, hitting, and tearing. The result was that this part was long fibrous. The fibers were tough. However, this step took a long time, since the green bark had to be peeled off and hard and difficult to break. One stalk contained many fibers. Fig. 5 illustrates how to separate the fibers from the Nipa palm stalks.

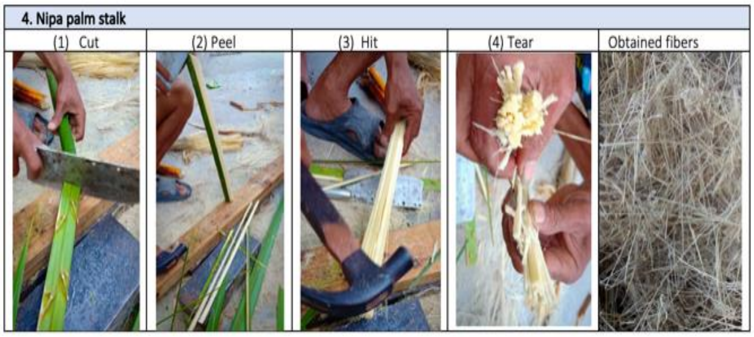


Fig. 5. How to separate the fibers from Nipa palm stalks.

Part 5. Sapok Jak (i.e., Nipa palm trunks)

There were four steps of making fibers: cutting, peeling, hitting, and tearing. The results showed that this part was the most fibrous. This was because this portion was large. This process took a long time to complete because the dark brown bark had to be removed. This was because the bark was difficult to break. After it hit, there was more flesh than fibers. The obtained fibers were tough and straight. The fibers were white in color. When it was dry, it turned light brown in color. Fig. 6 shows how to separate the fibers from the Nipa palm trunks.

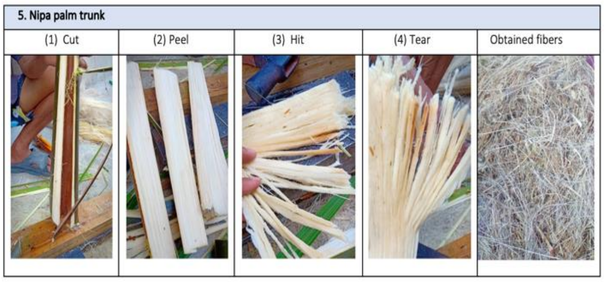


Fig. 6. How to separate the fibers from Nipa palm trunks.

From the process of separating the fibers from the Nipa palms above, Kan Mhong Jak (stalks of empty Nipa palm bunches) and Sapok Jak (Nipa palm trunks) were the most suitable. From all five parts, these two parts were used to make fibers for this present study. The two parts were dried in the sun. Ten kg of each part were brought to the measurement process to determine the differences between these two parts of the fibers in terms of size, toughness, and stretch. When they are measured, the best part will lead to the following process. The next step was to determine the physical properties of the obtained Nipa palm fibers. The fibers obtained from all five parts of the Nipa palms were tested using (i) Softener HSB and (ii) Texamina.

The method of soaking in the type 1 Softener HSB (soft and fluffy): Testing of Softener HSB (2 h). Fig. 7 illustrates a sample image of the fibers soaked in Softener HSB. After experimenting to determine the softness of the fibers using Softener HSB. The results showed that all five parts had positive responses. The properties of the fibers were found to be soft and smooth. The experiment took approximately two hours to complete. These findings suggest that Softener HSB is an effective solution for achieving soft and comfortable textiles.

Fig. 7. The sample image of the fibers when soaking in the Softener HSB.

1. The fibers from Nipa palm leaves were strong, not soft, and not fluffy because the shell of the leaves stuck to the fibers too much. Therefore, this reacted least to Softener HSB.
2. The fibers from the Nipa palm bunches were strong and sticky. When soaked in a softener, they were softer. They can be easily removed from shells. They slightly reacted to the Softener HSB.
3. The fibers from Kan Mhong Jak (stalks of empty Nipa palm bunches) soaked in the Softener HSB were clearly softer and fluffier. They can be torn to a smaller size. The fibers were tougher. They were the parts where the fibers could react to Softener HSB the most.
4. when soaked in the Softener HSB, the fibers from the Nipa trunks were soft and fluffy and could easily be torn. The fibers were long. However, when torn, they were easily torn, but not sticky. They were the part that the fibers reacted to Softener HSB moderately.
5. The fibers from Sapok Jak (i.e., Nipa palm trunks) soaked in softener HSB were noticeably softer. Since there were many fibers, they could have been torn to be smaller. The fibers were tougher. They were the parts where the fibers could react to Softener HSB significantly.

In conclusion, regarding the size of the fibers obtained from the process of separating the components of the fibers from the hand-made method and the experiment soaked in Softener HSB to determine the softness and smoothness of the fibers. The results showed that two parts had small fibers, and the reaction was significant. These two parts were (i) the fibers obtained from Kan Mhong Jak (i.e., stalks of empty Nipa palm bunches) and (ii) the fibers obtained from Sapok Jak (i.e., Nipa palm trunks) for use in the industrial system.

The method of soaking in the type 2 Texamina (soft and smooth): Testing of Texamina (2 hours). Fig. 8 illustrated the sample image of the fibers when they were soaking in Texamina.

Fig. 8. The sample image of the fibers when soaking in Texamina.

After conducting a basic experiment for approximately two hours to soak the fibers from all five parts that had responses to Texamina, we were able to determine the softness and smoothness of the fibers. The results indicate that the fibers are incredibly soft and smooth, making them ideal for various applications.

1. The fibers from the Nipa palm leaves were not soft and smooth, since the shells of the leaves were larger than the fibers. Therefore, they reacted the least to Texamina.
2. The fibers from the Nipa palm bunches were strong and sticky. When soaked in Texamina, they were softer and could easily be pulled out of the shells. The fibers were thick and reacted slightly to the Texamina.
3. The fibers from Kan Mhong Jak (i.e., stalks of empty Nipa palm bunches), when soaked in Texamina, were clearly smooth. They could be torn to be smaller. The fibers were tougher. These were the parts where the fibers could react to Texamina the most.
4. When soaked in Texamina, the fibers from the trunks were soft and smooth. They can be easily torn. The fibers were long. However, when torn, they were easily torn but not sticky. In addition, they were thick. The fibers were moderately reactive to Texamina moderately.
5. The fibers from Sapok Jak (i.e., Nipa palm trunks) were noticeably soft and smooth when soaked in Texamina. This is because there are many fibers. The fibers were torn to become smaller. Moreover, the fibers were tougher and more flexible. They could react significantly to Texamina.

Fig. 9 shows the results of the fibers obtained from all five parts of the Nipa palms after soaking in Softener HSB and then soaking in Texamina. In summary, the fibers obtained from Kan Mhong Jak (i.e., stalks of empty Nipa palm bunches) were most suitable for use.

Fig. 9. The fibers obtained from all five parts of Nipa palm after soaking in Softener HSB and then soaking in Texamina.

Step 2: Testing the properties of the Nipa palm fibers obtained from the yarn spinning process

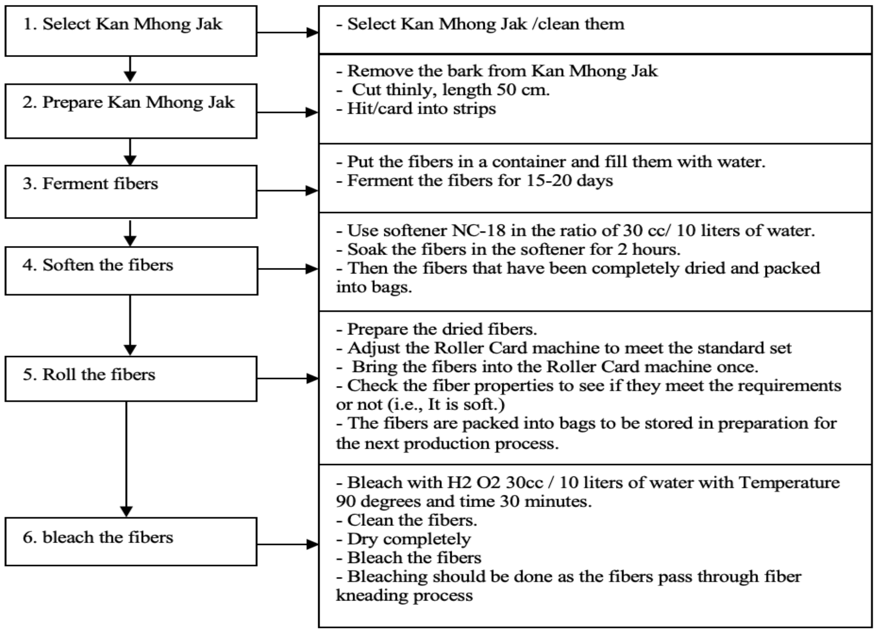


Fig. 10. The steps for experimenting Kan Mhong Jak (i.e., stalks of empty Nipa palm bunches) in the textile industry.

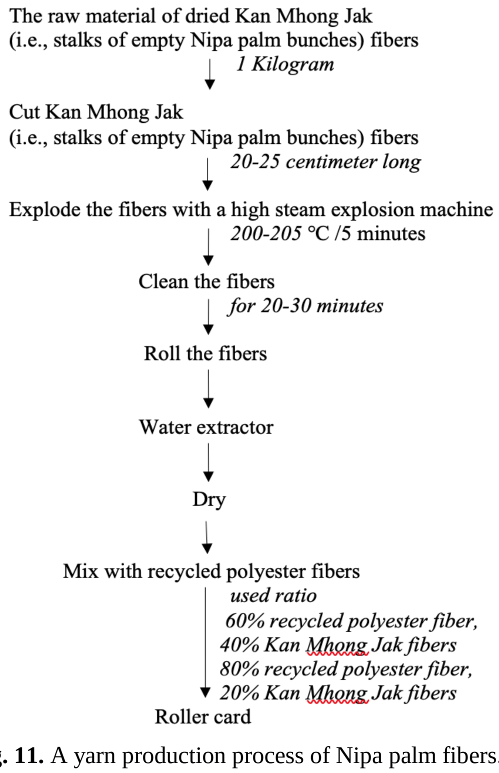


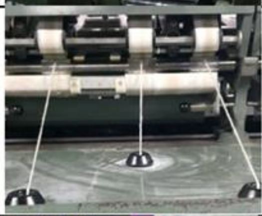
Fig. 11. A yarn production process of Nipa palm fibers.

Table 1 is a summary of yarn production process of Kan Mhong Jak (i.e., stalks of empty Nipa palm bunches).

RESULTS

After the Nipa palm fibers were woven and became fabric, they were assessed in terms of suitability by experts. The results are as follows: PM PALM No. 20 yarn had B-Force at 588.5 (gf) and B-Force 5.77 Newton, elongation at 6.37 %. PM PALM No. 35 had B-Force at 319.5 (gf) and 3.13 Newtons, elongation at 5.80%.

Table 1. Yarn production process: Kan Mhong Jak (i.e., stalks of empty Nipa palm bunches).

Step	Picture	Description
1		Dried Nipa palm fibers Length 20 - 25 cm.
2		Prepare Kan Mhong Jak fibers
3		Take the Kan Mhong Jak fibers into the high steam explosion machine, temperature 200-205 degrees Celsius for 5 minutes
4		After fiber explosion, there will be a mix of usable and unusable fibers that are obtained. Rinse with water and filter them with a sieve in order to separate only the fibers.
5		Take the washed fibers into the fiber sorting machine in the industrial system.
6		Mix the Nipa palm fibers with recycled polyester fibers.
7		Take the fibers into carding machine in order to mix them until they become homogeneous
8		Drawing / organizing fibers so that the fibers are arranged in a long line.
9		Threading the fibers as a single thread to obtain small fibers suitable for weaving
10		yarn winding
11		The fibers obtained are Fiber No. 35 - looks like a small and thin line Fiber No. 24 – looks thicker than Fiber No. 35.

The test results of Kan Mhong Jak fibers
(PM PALM No. 20).

Strength: Tested according to ISO 2062: 1993 (E) METHOD B	
B-Force (gf)	588.5
B-Force (newton)	5.77
Elongation (%)	6.37

- Tester: USTER TENSORAPID 3 V 6.1
- Test speed: 500 millimeters/minute
- Test distance: 500 millimeters

The test results of Kan Mhong Jak fibers (PM PALM No. 35).

Strength: Tested according to ISO 2062: 1993 (E) METHOD B	
B-Force (gf)	319.5
B-Force (newton)	3.13
Elongation (%)	5.80

- Tester: USTER TENSORAPID 3 V 6.1
- Test speed: 500 millimeters/minute
- Test distance: 500 millimeters

When the weaving fabric was mixed with recycled polyester fibers, it was easy to form. The vertical axis weaving process should be a mixed material. The horizontal axis was made from Nipa palm fibers. The fabric had a soft texture and was strong. It can be developed into other products to add value to materials for textile products. As can be seen, Kan Mhong Jak fibers, with a diameter of 2.45 millimeters, could withstand a maximum tensile strength of 12.80 kilograms. This finding is in line with the research conducted by Areechongcharoen (Areechongcharoen2013) concerning the development of textile products from lemongrass fibers, in that natural fibers can be developed and woven into fabrics suitable for textile products. Fig. 11 illustates the woven fabrics of PM PALM No. 20 yarn and PM PALM No. 35 yarn.

PM PALM No. 20 PM PALM No. 35

Fig. 11. The woven fabrics of PM PALM. No. 20 yarn and PM PALM No. 35 yarn

DISCUSSION

In this section, the results will be discussed according to the research objectives of this study, i.e., (i) to study the physical properties of Nipa palm fibers and (ii) to test the properties of the Nipa palm fibers obtained from the yarn spinning process. To study the physical properties of Nipa palm fibers, the researchers defined the criteria for assessing the size of the fibers obtained from the separation of the fiber components of Nipa palm fibers by soaking in Softener HSB and Texamina using two criteria: (i) to determine the softness and fluffiness values; and (ii) to determine the softness and smoothness values. This study aimed to analyze the fibers obtained from the separation of Nipa palm fibers' components and test their toughness and strength. It can be summarized that the results of the assessment of the Nipa palm fibers obtained from Kan Mhong Jak (stalks of empty Nipa palm bunches) revealed a perfect level. From the five parts of Nipa palms, Kan Mhong Jak (stalks of empty Nipa palm bunches) had many fibers. The fibers were long, thick, tough, and straight. The fibers were light brown. When soaked in Texamina, it was found to be noticeably softer, smoother, smaller, and stickier. This was the part where the fiber reacted most to Softener HSB and Texamina.Moreover, when the experimental fibers were soaked in Softener HSB, it was found that the fibers were noticeably softer and fluffier (particle size <50 nm). It is a Silicone Softener with small particle size, which can penetrate the fibers well. Therefore, the texture is soft and smooth. This corresponds to the research of Şengöz (Sengöz 2016), who found that it is a high-quality softener. In the textile industry, silicone softeners are used to make fabrics that are softer, smoother, and more flexible. It can be used with various fibers, such as cotton and polyester. In general, silicone does not dissolve in water. Emulsifiers should be used to facilitate dissolution because they contain silica as a component. This is typically in the form of oil-in-water or water-in-oil. To test the properties of the Nipa palm fibers obtained from the yarn-spinning process, the researchers used criteria for yarn production in an industrial system. The Yarn spinning process included testing two proportions: (i) 80% recycled polyester fibers/ 20% Kan Mhong Jak (i.e., stalks of empty Nipa palm bunches) fibers; and (ii) 40% recycled polyester fibers/ 60% Kan Mhong Jak (i.e., stalks of empty Nipa palm bunches) fibers, with 11 steps of the production process (Table 1). The result was No. 2 yarns, which were then tested for durability, strength, tensile strength, and elongation by the Textile Industry Development Institute. The results were presented in the results section. Interestingly, when weaving fabrics mixed with recycled polyester fibers, it was found that it was easy to form. The vertical core weaving process should use a composite material. The horizontal core was the Nipa palm fibers. The result was a fabric with soft texture and strength. Thus, they can be developed into other textile products. The properties of the Nipa palm fibers were also assessed in terms of suitability by experts in specific fields, which is consistent with the findings of Zou, Reddy, and Yang (Zou *et al.* 2011), who found that when polyester fibers were mixed with other natural fibers, the obtained fibers became soft and suitable for textile products. Nipa palms are a versatile resource that can be used for more than just as fibers. While the fibers are undoubtedly valuable, other products can be made from these equally important palms (Utama *et al.* 2018; Agung *et al.* 2020).

One such product is Nipa palm wine, a popular beverage in many parts of Southeast Asia. Sap from the palm is fermented to create a sweet and slightly alcoholic drink enjoyed by locals and tourists alike. Another product that can be produced from Nipa palms is roofing material. The leaves of the palm are sturdy and waterproof, making them an ideal choice for roofing. They are also lightweight, which makes them easy to operate (Foundation Encyclopedia of Thai Culture 1999; Chonlakup *et al.* 2009; Janyatham 2012). Regarding the fibers, several physical properties of Nipa palm fibers make them particularly suitable for weaving into fabrics (Agung *et al.* 2020). First, the fibers were extremely strong and durable. This means that fabrics made from these fibers will persist for a long time, even with regular use (Puspa *et al.* 2019). In addition, Nipa palm fibers are also very flexible, which means that they can be woven into a variety of different patterns and designs. This makes them a popular choice for traditional weaving techniques such as those used in batik and ikat fabrics (Chonlakup *et al.* 2009; Janyatham 2012). Nipa palm fibers are also soft and comfortable to wear (Huda *et al.* 2019). They are not scratchy or rough like other natural fibers, making them an excellent choice for clothing and other items in direct contact with the skin. The versatility and physical properties of Nipa palm fibers make them a valuable resource that can be used in various ways (Ahmed *et al.* 2017; Utama *et al.* 2018). Whether from textiles, roofing material, or even wine, these palms are a great choice (Zou *et al.* 2011; Sengöz 2016). As we continue to seek ways to reduce our environmental impact, it is vital to consider every aspect of our daily lives. One area of concern is the textile industry, which traditionally relies on synthetic materials that are not sustainable or environmentally friendly. However, recent research has shown that using Nipa palm fibers in textile production may provide a viable alternative. Nipa palm fibers are a natural and renewable resource that can be sourced locally in many areas. This means that their production has a much lower carbon footprint than synthetic materials often imported from other countries.

Additionally, using Nipa palm fibers can help to support local economies and provide jobs in areas where traditional textile production has declined. Furthermore, Nipa palm fibers have several advantages over other natural materials, such as cotton and wool. They are naturally resistant to pests and diseases, which means that they require fewer pesticides and herbicides for growth. They also have high moisture content, which makes them ideal for use in hot and humid climates. It is important to consider the entire life cycle of a product when evaluating its environmental impacts. While Nipa palm fibers may have lower carbon emissions during production, they may not be as durable as synthetic materials and require more frequent replacement. However, they are promising alternatives to traditional textiles and could play a key role in promoting more sustainable and ethical manufacturing practices.

CONCLUSION

Based on the development of plant fibers for textiles by the process from the beginning to the end and from the experiment, it resulted in one part of the Nipa palm that was obtained from the production process in the industrial system mixed with recycled polyester fibers in two different proportions. They were then tested until the fibers were suitable for weaving into fabrics. In addition, the woven fabrics were beautiful, strong, and suitable for further development and creation of other textile products. These fabrics were further developed to have a softer texture by applying softeners and adding special properties to the Nipa palm fibers. The fabrics can be used for home textile products such as clothing, suits, bathrobes, bags, shoulder scarves, scarves, cushions, curtains, and so on. This will result in plant fiber textiles being popular and generating income. Additionally, it can add value to Nipa palms, which are plants that grow naturally in the community to maximize their benefits. People who are interested in using plant fibers can apply the process of developing Nipa palm fibers for textiles, guidelines and criteria for material testing, and the fiber production process in the present study to textile products with similar target groups and manufacturers. Regarding recommendations for further research, more studies on other fibers that are mixed with natural fibers to add new materials in the textile industry should be conducted. This aims to add new materials and bring the knowledge gained to further study to be beneficial in the textile industry in the future.

ACKNOWLEDGEMENT

The researchers would like to express their great appreciation to the participants who provided valuable data for this study. Without their cooperation, the research would not have been possible. In addition, the authors would like to thank the reviewers of this article.

REFERENCES

Agung, M., Shyam, R & Lenggoro I 2020, Characterization of nipa palm fibers and their potential application in textile reinforcement. *Journal of Natural Fibers*, 17: 942-956, https://doi.org/10.1080/15440478.2019.1664503.

Ahmed, M, Ali, A, Aziz, HA, Jawaid, M, Alothman, OY & Asiri, AM 2017, A comprehensive review on the properties of nipa palm (nypa fruticans) fibers and its composites. *Journal of Natural Fibers*, 14: 737-755. https://doi.org/10.1080/15440478.2016.1224766

Ananwarapong, A *et al.* 2018, Development of the bag products from vetiver grass. Thai Wisdom Product. Rajamangala University of Technology, Fra Nakhon, 114 p.

Areechongcharoen, S 2013, Development of textile products from lemongrass fibers. Research in textile chemistry technology, Rajamangala University of Technology, Phra Nakhon, Thailand. 114 p.

Bamrungrak, N & Wattanatchariya, A 2001, Nypa palm: An economic crop of Mangroves, Bangkok: Office of the National Research Council of Thailand.

Cholsakorn, S *et al.* 2015, The development of textile products from Thai rice straw by the environmentally friendly technology. (Research Report), Thanyaburi: Department of Textile Industry, Rajamangala University of Technology Thanyaburi, Thailand.

Chonlakup, R *et al.* 2009, The concept of textile product development with special properties. and technical textiles. [accessed 8 January 2023]. Available on https://www.thaitextile.org/th/activities/detail.731.1.0.html

Development Program, 2018, Faculty of Arts, Rajamangala University of Technology Krungthep, Thailand.

Foundation Encyclopedia of Thai Culture 1999, Encyclopedia of Thai Culture Volume 7. Bangkok: Thai Cultural Encyclopedia Foundation Siam Commercial Bank, Thailand.

Huda, MS, Jawaid M, Paridah, MT & Khalil, HA 2019, A review on nipa palm (nypa fruticans wurmb) fibers and its composites. *Journal of Natural Fibers*, 16: 488-508, https://doi.org/10.1080/15440478.2018.1512056.

Janyatham, J 2012, Product development From bamboo fiber, Bangkok: Odeon Store, Thailand.

Phuttachot, B *et al*. 2019, The design and handcraft work development at Huai Kla Reservoir using a variety of bio diverse fiber plants. Case Study: Huai Kla self-help settlement sub-district in Sisaket Province (Research Report), Department of Textile Industry Sisaket Rajabhat University, Thailand.

Puspa, IP, Ranggawarsita, A, Masduki, AA, Widiyanti, N & Mas'ud, A 2019, The Potential of Nipa Palm Fiber for Textile Applications: A Review. IOP Conference Series: Materials Science and Engineering, 495: 012052, https://doi.org/10.1088/1757-899X/495/1/012052.

Sengöz, NG 2016, Practicing hypothesis tests in Textile Engineering: Spinning Mill Exercise, University of Gaziantep, MSc. Dissertation in Textile Engineering, Turkey, DOI: 10.5772/intechopen.105643.

Utama, MI, Reza, M, Sapuan, SM, Jawaid, M & Hakeem, KR 2018, Nipa Palm Fibers and Its Reinforced Polymer Composites: A review. *Journal of Reinforced Plastics and Composites*, 37: 663-673. https://doi.org/10.1177/0731684418767954.

Zou, Y, Reddy, N & Yang, Y 2011, Reusing polyester/cotton blend fabrics for composites.Compos. Part B :(42 - 763 770 [accessed 20 December 2022]. Available on https://www.phisit.com/knowledge/ Silicone-softener.

Bibliographic information of this paper for citing:

Piguntong, P, Soodsang, N 2023, Development of Nipa palm fibers for textiles. Caspian Journal of Environmental Sciences, 21: 841-852.