ABE
Agricultural and Biological Engineering
https://ph04.tci-thaijo.org/index.php/abe/index
Published by the Faculty of Engineering, Khon Kaen University, Thailand

Development of a banana fiber extraction machine and factors affecting fiber quality for textile use

Rewat Termkla[1], Ratanarekha Atchariyapitak[2], Ruttanachira Ruttanaprasert[2] and Lakkana Pitak[1]*

[1]Department of Agricultural Machinery, Faculty of Agriculture and Technology, Rajamangala University of Technology Isan Surin Campus, Surin, 32000, Thailand
[2]Department of Plant Science, Textiles and Design, Faculty of Agriculture and Technology, Rajamangala University of Technology Isan Surin Campus, Surin, 32000, Thailand

*Corresponding author.
Email address: lakkana.ph@rmuti.ac.th

Received 7 April 2025
Accepted 23 May 2025

Abstract

This study aims to evaluate the efficiency of a banana fiber extraction machine. The banana fiber separator has a 1 hp motor is used as the power source to rotate a 1 inch shaft attached to beating blades. Conduct tests at three different speed rotational; 450, 600, and 750 rpm. The banana sheaths are beaten with the blades until the pulp comes off, producing fibers. The extracted fibers can be separated, and the crushed banana sheath residue drops into the rear waste chute of the machine. The test results revealed that the suitable operating speed for the banana fiber separator is within the range of 750 rpm. The capacity, efficiency, and fiber strength of 61.03 kg/h, 98.86%, and 2,390.83 cN, respectively. The average fiber separation rate is 58.43 kg/h, when compared to manual labor, which can separate an average of only 2.87 kg/day. Therefore, using a banana fiber extraction machine can replace manual scraping, reducing labor requirements. Moreover, the machine is easy to operate and produces high-quality fibers in quantities sufficient to meet demand.

Keywords: Banana fiber, Natural fiber, Textile, Fiber separator, Extracting machine

1. Introduction

Banana exports generate annual revenue of no less than 3,000 million Baht, with an average yield of 3,360 kg/rai/y. As of December 2023, the average selling price was 8 – 10 Baht/kg [1]. During periods of banana leaf scarcity in the dry season (February 2023), prices increase to 11-14 Baht/kg. It should be noted that 60% of banana exports are destined for China, primarily the provinces of Sichuan, Zhejiang, Jiangsu, and Anhui. There has been an increase in imports, particularly during the Chinese New Year festival, including from Vietnam, South Korea, Japan, and Hong Kong [1]. Bananas, being a versatile plant that can be cultivated in diverse environments, have planting areas distributed across the country. Distribution channels encompass both fresh fruit and processed products, offering a wide range of options [2]. The components of the banana plant are highly valuable. Not only is it an important food source, but its various parts are also utilized in many areas, including agriculture, industry, and handicrafts. For example, the banana sheath. The banana sheath is a part of the banana plant's trunk that is useful. Using banana sheaths in various ways not only helps reduce waste but also makes efficient and environmentally friendly use of natural resources, such as turning them into banana fibers for textiles [2]. Therefore, it is interesting, especially the banana fiber, which has been brought up in many discussion forums to focus on the development of plant fibers from agricultural waste. In India, there is a variety of banana known as *Arecanut*, which is abundant and interesting. It has a diameter of 5.6 – 11 μm and a cell wall thickness of 2.2 μm. The fibers have been extracted using fermentation, mechanical, chemical, and biological methods. With techniques and methods based on wisdom, all of which have been developed from the past to the present [2].

Mechanical extraction methods require peeling the bark to obtain a large quantity of fibers with the best physical properties, which affects the strength and tensile strength of the fibers. While the chemical extraction of fibers is a method that determines the hemicellulose content of the fibers. For the fermentation method, the fibers obtained are coarse and of low quality compared to other methods, due to the loss of cellulose in the fibers [2]. However, there have been studies on the use of agricultural materials to produce fibers, such as M. Grégoire, et al., [3] study to Investigation of the potential of hemp fiber straws harvested using a combine machine for the production of technical load-bearing textiles. Hemp (*Cannabis sativa* L.) for high-value textile applications: The effective long fiber yield and quality of different hemp varieties, processed using industrial flax equipment [4]. Grégoire, et al., [5] comparing flax and hemp fibres yield and mechanical properties after scutching/hackling processing. Efficient extraction of technical fibers from hemp in an ethanol-water mixture [6]. Musio, et al., [7] optimizing Hemp fiber production for high performance composite applications. Manian, et al., [8] extraction of cellulose fibers from flax and hemp. Innovative rice straw fibers mixed fibers from cocoons to develop textilesto further develop fashion lifestyle products: a case study of Khwao Sinarin Sub-district, Khwao Sinarin District, Surin Province [9]. Soiraya, et al., [2] develop environmentally friendly packaging from banana fibers for ready-to-eat food products to study the drafting, review and improvement of the draft, and create prototypes of the packaging made from banana fibers. Ritthisorn, [10] study on the production of pulp from banana pseudostems using biological methods with the fungi *Trichoderma viride*, *T. harzianum*, and *T. hamatum*. *T. viride* is the most suitable for producing paper from banana pseudo stems using biological methods. Inpakdee, [11] study the physical properties of banana fibers improved through a biological process, extract natural dyes from leftover banana pulp after the fiber separation process, and develop prototype community textile products creatively using naturally dyed banana fibers. Atchariyapitak, et al., [12] study of banana fibers for the development of clothing design and tailoring found that banana fibers separated from banana pseudo stems using traditional hand-separation methods have limited length and cannot be woven back and forth. This is because the banana fibers are very thin and may break upon friction. Rahamaththulla, et al., [13] design and develop a process for extracting high-quality natural fibers from banana stems. It was found that factors affecting the quality of the fibers include roller speed, feed angle, and distance, which also impact the production volume of the fibers. If these factors are chosen correctly, the quality and yield of the fibers will increase.

Surin Province, Thailand primarily has agriculture as its main occupation, and weaving is pursued after the main occupation each year. Additionally, bananas are grown in large quantities in the area, mostly for harvesting. The banana sheath is usually discarded. Therefore, the researcher developed a banana fiber separator to add value to agricultural waste materials and provide an alternative fiber for farmers who want to reduce costs from using expensive silk. Study the rotational speed factors that affect the efficiency of the machine and the quality of the fibers. This research aims to develop a banana fiber separator with a simple design, so that everyone can use and maintain it. And to test the quality of the high-quality fibers, they can be developed into textiles for the industry.

2. Materials and methods

2.1 Fiber extraction machine

The banana fiber separator has a height of 74 cm, a length of 70 cm, and a width of 74 cm. It uses a 4 inch drive pulley, a 10 inch driven pulley, a 10 inch wide blade, long blade 30 cm, and a 1 inch roller to flatten the banana sheath and control the input and output direction. The motor transmits power to the drive pulley, and the drive pulley transmits power to the driven pulley, causing the shaft attached to the beater to rotate. Then, place the banana sheath into the feed chute, move the banana sheath into the beater, until the fibers of the banana sheath break apart and form fibers. When it reaches the designated point, pull it out slowly to obtain the fibers.

2.2 Testing the efficiency

Prepare banana sheath with a length of 80 – 110 cm and weigh them. Then, test them at three speed levels: 450, 600, and 750 rpm, following the testing procedure shown in Figure 1. After preparing the banana sheath to the specified size, feed the into the machine. Then, move the banana sheath according to the centrifugal force of the beating blades until they reach the designated point. Pull the banana sheath out of the feeding slot to obtain banana fibers. Weigh the obtained fibers and weigh the remaining banana pulp after beating. Use the obtained data to calculate the efficiency and capability.

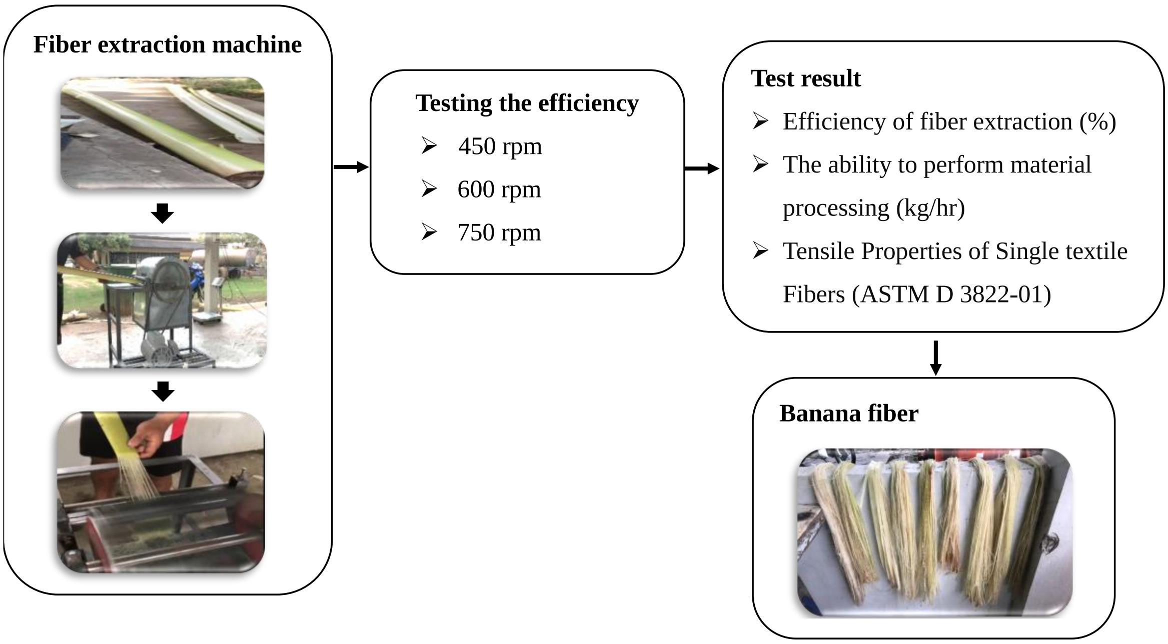


Figure 1 flow chart of fiber extraction machine testing

Which determines the efficiency of the separator and the capability of processing the input materials by the weight ratio of all materials fed into the machine per unit of operational time, including the rate of electrical energy consumption as Equations 1 and 2, respectively [14].

$$EF = \frac{A}{B} \times 100 \quad (1)$$

Where: EF = Efficiency of fiber extraction (%)
A = Length after fiber separation (cm)
B = Length before fiber separation (cm)

$$C_m = \frac{M}{T} \tag{2}$$

Where: C_m = Capability to perform material processing (kg/h)
M = The total weight of the materials feed into the machine (kg)
T = Time of work (h)

2.3 Fiber quality testing

The banana fibers obtained from the mechanical separation of fibers and test their quality through visual and tactual examination, following the quality grading method according to the agricultural product standard (TAS 9042-2015) [15] as shown in Table 1.

Table 1 Criteria for evaluating general quality and defects of silk

Set level	Level	Description of general quality characteristics and defects
4	Good	The silk fibers are well-aligned and orderly, with a smooth touch. The fibers are glossy, with no abnormalities or defects found
3	Normal	The silk fibers are relatively well-aligned and orderly, with a fairly smooth touch. The fibers are glossy and uniformly colored, with minor defects found
2	Fair	The silk fibers are arranged irregularly, feel less smooth to the touch, lack glossiness, and show many abnormalities and defects
1	Below Standard	Silk fibers with more defects than an acceptable level or with significantly varying colors

And test the strength of the fibers (cN) according to the standard method ASTM D 3822-01 Standard test method for tensile properties of single textile fibers. Record the breaking force of individual specimens to three significant digits as read directly from the tension testing machine, expressed in cN (gf). And calculate the breaking tenacity of individual specimens to three significant digits, using Equations 3 [16].

$$Y = \frac{F}{D_L} \tag{3}$$

Where: Y = breaking tenacity in mN/tex (gf/den)
F = breaking force in cN (gf)
D_L = linear density in tex (denier)

3. Results and discussion

3.1 The performance results of the banana fiber extraction machine

The operation of the machine starts with the motor transmitting power to the drive pulley. The drive pulley transmits power to the driven pulley to rotate the shaft connected to the beating blades, causing the blades to work. When banana sheath is feed into the inlet, the eight beating blades will beat the banana sheath fibers. When the banana sheath is pulled out from the roller channel, only the banana fibers remain. The banana sheath fibers will fall into the waste collection channel at the back of the machine.

3.2 Performance of the banana fiber separator

The performance test of the banana fiber separator, as shown in Table 2 and Figure 2 (A), it was found that at a speed of 450 rpm, the average efficiency of banana fiber separation was 98.40%, and at a speed of 600 rpm, the average efficiency of banana fiber separation was 98.55%. Both speeds had low beating speeds, requiring a longer time to separate the banana pulp from the fiber. At a speed of 750 rpm, the average efficiency of banana fiber separation was 98.86%, which used a high beating speed, allowing for a stronger and faster separation of the banana.

Table 3 and Figure 2 (B) testing the operational capability of the banana fiber separator machine. From visual and tactile observation of the fiber quality, the fibers were found to be at normal and acceptable levels (according to the fiber quality assessment criteria in Table 1). Therefore, the fiber separation capability of the banana at three different speeds was determined. At speeds of 450 and 600 rpm, the machine could separate an average of 47.68 and 49.88 kg/h, respectively. At a speed of 750 rpm, the machine could separate an average of 61.03 kg/h. Which Table 4 shows the statistical analysis, where the blade speeds a statistically significant difference ($p < 0.05$). The speed of the blades will affect fibre separation; increasing the speed will also enhance the efficiency.

Table 2 Efficiency of banana fiber extracting machine

Speed (rpm)	Set	Length before testing (cm)	Length after testing (cm)	Efficiency (%)
450	1	103.00	100.00	97.08
	2	118.00	117.00	99.15
	3	99.00	98.00	98.98
600	1	90.00	89.00	98.88
	2	75.00	74.00	98.66
	3	106.00	104.00	98.11
750	1	84.00	83.00	98.80
	2	88.00	87.00	98.86
	3	94.00	93.00	98.93

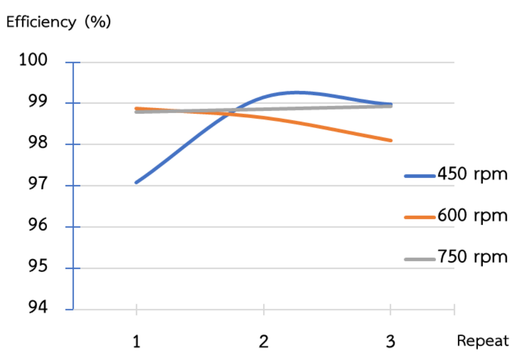
Table 3 Capability of banana fiber extracting machine (leaf sheaf of banana tree 1 kg)

Speed (rpm)	Set	Time (s)	Weight of fiber (kg)	Weight of Sheath (kg)	Capability (kg/h)
450	1	68	0.25	0.60	45.00
	2	74	0.25	0.70	46.22
	3	66	0.25	0.70	51.82
600	1	61	0.20	0.65	50.16
	2	62	0.15	0.75	52.26
	3	61	0.20	0.60	47.21
750	1	55	0.30	0.65	62.18
	2	57	0.25	0.75	63.16
	3	53	0.20	0.65	57.74

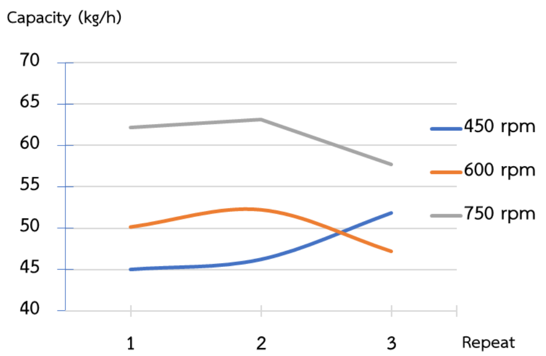
Table 4 Analysis of variance of the efficiency of fiber extracting machine

Source of Variation	df	SS	MS	F
rotational speeds	2	55995.80	27997.9	43930.84*
Within Groups	24	15.30	0.6	
Total	26	56011.10		

Note: * is significant ($p<0.05$), ns is non-significant.



(A) Efficiency of banana fiber extracting



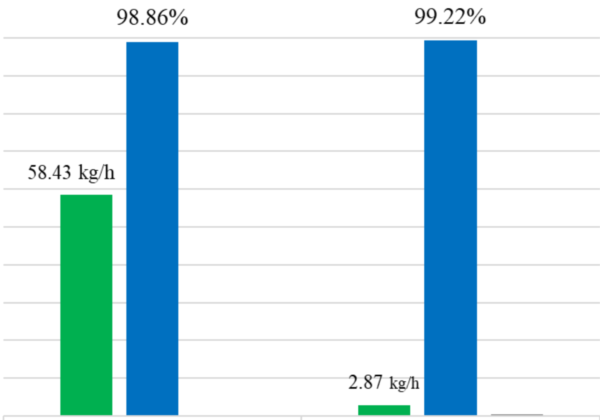
(B) Capability of banana fiber extracting

Figure 2 (A) Efficiency of banana fiber extracting, and (B) Capability of banana fiber extracting

Figures 3, 4(A), and 4(B) compare banana fiber separation between a fiber separation machine and manual labor. The tests were conducted within one day, averaging 6-8 h of work. Using the fiber separation machine at a speed of 750 rpm yielded normal quality fiber, averaging 58.43 kg/h, with an electricity cost of 14.58 Baht/day or an amount 0.44 USD/day. In contrast, manual fiber separation also produced normal quality fiber but only averaged 2.87 kg/day, requiring a labor cost of 300 Baht/day or an amount 9.14 USD/day.

Table 5 use of fiber separation machines at speeds of 450 and 600 rpm results in fibers of acceptable quality. This means the silk fibers are disorganized, feel slightly less smooth to the touch, lack luster, and exhibit numerous defects. When using a speed of 750 rpm, the fibers obtained are of normal quality, meaning the silk fibers are relatively well-organized, feel reasonably smooth, have luster, and exhibit uniform color with minor defects, similar to fiber separation by manual labor (according to agricultural product standards (TIS 8002-2556) as shown in Table 1). The average fiber strength is 2,390.83 cN, while the textile standard for yarn strength is 6.711 cN.

Which is according with the research of Autcha [17] the ratios of 70:30, 60:40, and 50:50, the average tensile strength was found to be 11.2, 10.9, and 10.8 N, respectively. This is consistent with the research by Rahamaththulla et al., [13], which reported an ultimate strength of 198.9 – 780.3 MPa. The tensile strength of the fibers affects the quality of the textiles, as weaving involves relatively high impact forces. Fibers with higher tensile strength can better withstand these impacts.



	Machine	People
Capacity (kg/h)	58.43	2.87
Efficiency (%)	98.86	99.22
Standard deviation (SD)	0.23	0.48

Figure 3 The capability and efficiency of banana fiber extracting between machine and people

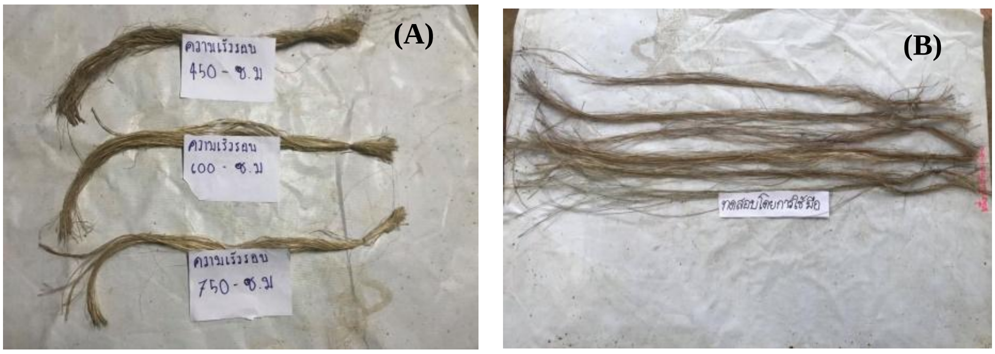


Figure 4 (A) Banana fiber of machine and (B) Banana fiber of people

Table 5 Banana fiber of quality

Method	Speed (rpm)	Level of quality (TAS 9042-2015)	Strength of fiber (cN)
Machine	450	2	2,350.33
	600	2	2,384.50
	750	3	2,473.00
People	-	3	2,355.50

4. Conclusions

The banana fiber separator uses a motor to drive a shaft attached to 8 beating blades. The blades rotate and whip the banana pulp until only the banana fibers remain. Testing the efficiency of banana fiber separation at a speed of 750 rpm showed an average separation efficiency of 98.86%. Which results in fibers of normal quality, meaning the silk fibers are relatively well-organized and orderly. They feel quite smooth to the touch, have a shiny appearance, and a uniform color. Minor defects may be present. Additionally, the banana fiber separator is easy to use, producing high-quality fibers that meet demand. In developing the machine, stainless steel should be used for its construction as it prevents rust and is easy to clean. Additionally, the number of banana sheath should be increased from 8 to 10 to make it easier and quicker to extract the banana fiber, thereby enhancing the efficiency of the banana fiber separation machine.

5. Acknowledgements

This work also supported by Department of Agricultural Machinery, Faculty of Agricultural and Technology, Rajamangala University of Technology Isan, Surin Campus, Thailand.

6. References

[1] Office of Agricultural Economics. Agricultural Economic Reports: 1st [Internet]. 2024 [cited 2025 March 16]. Available from: https://www.oae.go.th/assets/portals/1/fileups/bappdata/files/Outlook_Q1_2567.pdf.

[2] Soiraya B, Phuenpipob C, Tungsatitporn D, Siripun A, Theeramongkol P. The development of green packaging from banana fiber for instant food products. RMUTP Research Journal. 2013;7(1):9-24. Doi; 10.14456/jrmutp.2013.18.

[3] Grégoire M, Barthod-Malat B, Labonne L, Evon P, De Luycker E, Ouagne P. Investigation of the potential of hemp fibre straws harvested using a combine machine for the production of technical load-bearing textiles. Industrial Crops & Products. 2020;145:111988. https://doi.org/10.1016/j.indcrop.2019.111988.

[4] Vandepitte K, Vasile S, Vermeire S, Vanderhoeven M, Van der Borght W, Latr´e J, De Raeve A, Troch V. Hemp (*Cannabis sativa* L.) for high-value textile applications: The effective long fiber yield and quality of different hemp varieties, processed using industrial flax equipment. Industrial Crops & Products. 2020;158:112969. https://doi.org/10.1016/j.indcrop.2020.112969.

[5] Grégoire M, Bar M, De Luycker E, Musio S, Amaducci S, Gabrion X, Placet V, Ouagne P. Comparing flax and hemp fibres yield and mechanical properties after scutching/hackling processing. Industrial Crops & Products. 2021;172:114045.

[6] Lyu P, Xia L, Jiang X, Liu X, Xu W, Hurren C, Wang X. Efficient extraction of technical fibers from hemp in an ethanol-water mixture. Industrial Crops & Products. 2022;178:114620. https://doi.org/10.1016/j.indcrop.2022.114620.

[7] Musio S, Müssig J, Amaducci S. Optimizing Hemp fiber production for high performance composite applications. Front. Plant Sci. 2018;9:1702. doi: 10.3389/fpls.2018.01702.

[8] Manian AP, Cordin M, Pham T. Extraction of cellulose fibers from flax and hemp: a review. Cellulose. 2021;28:8275–94. https://doi.org/10.1007/s10570-021-04051-x.

[9] Atchariyapitak R, Ruttanaprasert R, Pitak L, Dungsri K. Innovative rice straw fibers mixed fibers from Cocoons to develop textilesto further develop fashion lifestyle products: A Case Study of Khwao Sinarin Sub-district, Khwao Sinarin District, Surin Province. Journal of Community Development Research (Humanities and Social Sciences). 2022;15(3):15-26. https://doi.org/10.14456/jcdr-hs.2022.22.

[10] Ritthisorn S. Biopulping from banana pseudo - stem of Num-Wa. Burapha Science Journal. 2013;18(2):161-71.

[11] Inpakdee C. Fibers development and natural dyeing extraction from banana tree for creative communities textile product design. Graduate School Thesis, Naresuan University, Doctor of Fine Arts Program, Art and Design Major. 2024.

[12] Atchariyapitak R, Ruttanaprasert R, Kruapukdee A, Pitak L, Promnog P. Develop the design and tailoring of garments from Surin ethnicity to international. The 12th National Academic Conference of Rajamangala University of Technology Surin, September 16-17, 2021.

[13] Rahamaththulla S, Premnath S, Ravi V, Madheswaran S, Jayakumar N. Design & fabrication of banana fiber extracting machine. International Journal for Scientific Research & development. 2018;6(1):390-2.

[14] Chuan-Udom S. Grain harvesting machines. Khon Kaen: Khon Kaen University. 2013.

[15] Office of Agricultural and Food Standards. Raw silk volume 3: sampling and testing methods for machine reeled silk yarn. Thai agricultural standard (TAS 9042-2015), Ministry of Agriculture and Cooperatives ICS 59.060.10 ISBN. 2015.

[16] ASTM international. Standard test method for tensile properties of single textile fibers. ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. 1995.

[17] Autcha S. The development of fancy yarn from banana and cotton fiber blend. Master of Home Economics, Major Program Home Economics (Graduated School) Home Economics of Technology, Faculty of Home Economics Technology, Rajamangala University of Technology Phra Nakhon. 2009.