Study of Factors Affecting the Efficiency of Separation Machines for the Strength of Fibers

Rewat Termkla[1], Ruttanachira Ruttanaprasert[2], Ratanarekha Atchariyapitak[2], Kiartiphum Duangsri[2], Arunsak Boonphum[1] 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. E-mail address: lakkana.ph@rmuti.ac.th

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Abstract

Using natural fibers helps reduce the use of fibers separated from environmentally harmful materials. Also, natural fibers reduce agricultural waste and add uniqueness to the fibers. Therefore, the objective of this research was to develop the fiber separation machine and test the efficiency of hemp fiber separation as a tool for peeling hemp fiber. The fiber separation machine consists of a beating blade assembly, a feed chute, a power transmission unit, and a waste discharge chute for the leftover material after fiber extraction. Test factors are as follows: preparation of hemp stalks (mashed stem and no mashed stem), water absorption (6, 12 hr), blade angle (0°, 15°), a set of feeds (1, 2, 3 stems), and speeds of blade (300, 400, 500 rpm). The developed hemp fiber separator effectively separates fibers from hemp stalks. Optimal performance was achieved by pre-crushing the stalks, soaking them for 6 hours, and using a blade angle of 0° at 400 rpm. With a feed rate of two stems, the machine achieved a capacity of 5.52 kg/hr, a separation efficiency of 98.20%, a post-separation loss of 0.98%, and a fiber strength of 3008.83 cN. In the operation of the machine, it consumes 0.40 kW/hr. The payback period for the hemp fiber separator is approximately 1.5 months. The fibers obtained are standardized and can provide more options for textile products, allowing communities to achieve sustainable self-reliance.

Keywords: separation machine, fiber separation, textile industry, hemp fibers, fiber strength

Introduction

Sustainable development has been a concept of interest in recent years. Although it is seen as a trend, living with an understanding of sustainability reflects an unavoidable reality in the global context. It is well known that textiles and fashion are among the major contributors to environmental pollution, especially organic materials that are expensive and consume vast amounts of water, as well as the dangers of synthetic fibers to ecosystems (Haug et al., 2022). Newly developed fibers and recycled fibers have begun to emerge in the industry (Thailand Textile Institute, 2025). When considering the export value of the four main products: synthetic fibers, yarn, fabric, and clothing, as at January 2024, artificial fibers increased both month-on-month (MoM) and year-on-year (YoY) over 2023. Clothing expanded due to demand from major trading partners. Thailand's textile and garment exports (January-September 2024): Total export value was USD$4,612.3 million, an increase of 1.5% (YoY), exports to the USA (+8.5%), Vietnam (+9.6%), and China (+5.2%). Regarding imports, the value of imported yarn increased by 4.4% (YoY). The volatility of yarn reflects the adaptation of the supply chain (Thailand Textile Institute, 2025). From the study of various government policy information, the Textile Industry Development Institute of the Ministry of Industry aims to accelerate the Thai textile industry towards

Thai eco-fiber by weaving pineapple leaves, hemp stalks, silk remnants, and agricultural and industrial waste into prototype fabrics and then processing them into everyday products. Hemp is an environmentally friendly economic crop that is easy to grow, adapts very well to the environment, likes sunlight, grows quickly without the need for fertilizers or pesticides, is drought-resistant, and uses little water. Additionally, it enriches the soil and absorbs pesticides (DITP, 2025). Thailand has long utilized hemp, particularly in textiles, where hemp has been cultivated and processed according to the wisdom of the Hmong tribe. Most of the benefits were derived from the bark of the stem, which has high-quality fibers. These were then made into clothing and household items, such as traditional tribal attire, thread for tying wrists or performing various rituals, bowstrings, or general-use ropes (Weerachai, 2021). The bark of the hemp stalk, which is used to make fibers, has long fibers that are durable, highly flexible, lightweight, resistant to mold and bacteria, with good moisture-wicking properties. The production process includes the steps of cutting the hemp stalk, drying the hemp stalk, peeling the bark, beating the fibers, splicing the hemp fibers, and spinning the hemp fibers into yarn, with weaving as the final step (Weerachai, 2021). Therefore, hemp fiber is a natural fiber, traditionally used, that is durable, flexible, odor-absorbing, and breathable. Hemp fiber is globally recognized as an environmentally friendly fiber, contributing to sustainable agricultural systems.

Research studies on textiles, natural fibers, and methods for fiber production, such as hemp fibers extracted via the "all fiber" opener, exhibit superior strength (660 MPa) and length (~5 cm) for technical textiles, despite kink defects, positioning them as a sustainable alternative to hammer-milled fibers in composites and geotextiles (Grégoire et al., 2020). Field-retted hemp, processed on flax equipment, yields strong fibers (37.6–45.3 cN/tex) at 36.2% extraction (~1 ton/ha). Uniform 1-meter stems via mechanized harvesting are critical to optimize flax-line compatibility and fiber quality (Vandepitte et al., 2020). Though requiring surface treatments for moisture/polymer compatibility, natural fiber composites remain promising sustainable materials, warranting further development to unlock their full industrial potential as viable conventional alternatives (Elfaleh et al., 2023). Optimized processing enables hemp to yield 18% long fibers with textile/composite-grade quality. While 20% weaker than flax, hemp's comparable per-hectare productivity and sustainability position it as a viable alternative, contingent on industrial-scale optimization to maintain fiber integrity (Grégoire et al., 2021). An ethanol-water mixture (30:70) proved superior to traditional alkaline degumming, effectively removing gums while protecting fiber strength (11.1% increase to 34.2 cN/Tex) and reducing yellowness. This eco-friendly method offers a promising industrial-scale solution for high-quality hemp fiber extraction (Lyu et al., 2022). Processed on flax machinery, hackled hemp demonstrates performance comparable to premium flax, validating its potential for high-value composites. Strategic optimization of agronomy and processing can revitalize Europe's hemp fiber sector (Musio et al., 2018). The review by Manian et al. (2021) underscores flax and hemp's resurgence as sustainable fibers, stressing the need to refine retting, degumming, and delignification processes alongside agronomic practices. Renewed focus on these crops can bridge traditional knowledge with modern eco-friendly material demands (Manian et al., 2021). Coir fibers' thermal insulation, durability, and eco-friendly nature position it as a valuable reinforcement for sustainable bio composites. Research confirms its potential to enhance material performance while reducing environmental impact, particularly in heat-insulating applications (Mahmud et al., 2023). Natural fibers, such as cotton, jute, hemp, and emerging sources such as pineapple leaf and milkweed, are gaining renewed attention for their biodegradability, mechanical strength, and versatility in textiles and medical applications (Umamageshwari &

Manonmani, 2021). Natural fibers such as cotton, wool, silk, and flax play a vital role in our daily lives due to their eco-friendliness, affordability, and versatility (Parasakthibala & Monisha, 2022). The strong consumer preference for Nypa palm fiber textile designs, with clothing and bags receiving the highest satisfaction scores ($\bar{x}$=4.52) (Pigunthong, 2022). A semi-automated fiber separation process produced uniform whitish fibers, while biological treatment with lye solution achieved optimal lignin reduction (70.62%) despite greater weight loss (40.50g). SEM analysis confirmed characteristic plant fiber roughness, validating the processing method's effectiveness for textile applications (Inpakdee, 2024). Hemp is a strong fiber plant; a variety with the potential for fiber production is the PRF7 variety (Yanaphan et al., 2023). A semi-automatic silk reeling machine demonstrates significantly higher efficiency (121.9 g/h) than traditional methods (15.87 g/h), producing 8 times more silk per hour while maintaining optimal processing temperatures. This innovation offers a substantial productivity improvement for silk production (Payom, 2012). The optimized yarn tension adjustment device significantly improved silk weaving efficiency, reducing adjustment time by 71.53% (to 121.45 seconds) and decreasing yarn misalignment by 22.04 cm. This innovation also minimized material waste, saving 403.2 meters of yarn (97.39% reduction) per 10 silk pieces, demonstrating substantial productivity and cost benefits (Rithinyo et al., 2560). Based on the research discussed above, fiber producers should choose methods suitable for the characteristics of that particular plant. This ensures high-quality fibers that can be further developed.

The process of separating hemp fibers for textile production follows the traditional method of 1. Cutting the hemp stalks, 2. Drying the hemp stalks, 3. Stripping the bark, 4. Beating the fibers, 5. Splicing the hemp fibers, 6. Spinning the hemp fibers into yarn, 7. Twisting the yarn, and 8. Weaving into yarn. The entire process relies primarily on human labor. The operators must possess expertise and specialized techniques to produce high-quality and strong fibers suitable for use as textiles. From the fiber separation process, operators must practice until they become proficient. During the operation, it may cause fatigue. This is because the fiber separation involves multiple steps and takes approximately 3 to 4 weeks to complete. Therefore, the researchers have considered the development of a hemp fiber separator machine to make it easier for farmers to use, reduce fatigue during operation, and shorten the time for drying hemp stalks, stripping the bark, and grinding the fibers. The factors that affect the efficiency of the machine and the quality of the fibers have been studied, including the preparation of hemp stalks, absorption of water, blade angle, a set of feeds, and the speed of the blade. The objective is to ensure that the fibers are relatively well-aligned and shaped uniformly, with minor defects found. This achieves high-quality fibers, providing an alternative for textile products, reducing the cost of purchasing silk, and enabling the community to be self-sufficient and sustainable.

Methods and Materials

1. Preparation of hemp stems

The hemp stalks should be processed 90 to 120 days after harvesting, and were cut to approximately 100 - 120 cm in length, and then pounded using a stick or hammer to soften the fibers (in the traditional pounding method). The stems were then mashed by soaking in water for 6 to 12 hr. The part of the stem that was not mashed was also soaked in water for 12 hr, ensuring maximum absorption of water. After soaking in water, the hemp stems were then cleaned and dried in a hot air oven (Memmert Universal Oven UN450) at a temperature of 105°C for 24 hours, or until the weight is constant. The moisture content was then determined, using Equation 1 (AOAC International, 2000). Preliminary tests showed that water absorption occurred after 12 to 24 hours of soaking (see Table 1). The moisture content and peeling results did not show significant differences. Therefore, to reduce the work time, we chose to soak the hemp stems for a maximum of 12 hr, at which time we proceeded to peel the stems using the developed hemp fiber separator machine.

$$M_w = \frac{(w_1 - w_2)}{w_1} \times 100 \quad (1)$$

Where M_W = moisture content (%), w_1 = weight of sample before drying (g), and w_2 = weight of sample after drying (g) (AOAC International, 2000).

Table 1 Moisture content of hemp stalks

Soaking time (h)	Average moisture content (%)
Dry	5.21
After harvesting within 15 days (fresh)	28.89
3	19.53
6	34.26
12	44.55
24	45.54

Fresh hemp had a moisture content of 28.89%. To reduce the soaking time needed to achieve a similar moisture content, a 15° blade angle was tested. This test involved preparing a mashed stem with soaking times of 6 hours and 12 hours. The goal was to minimize study variables that do not affect fiber quality. During the test, the feeder gap was set at 2 mm, the stem size was standardized, and the moisture level was compared to fresh samples to control for potential constraints.

2. Development of the hemp fiber separation machine

To make it easy for operators to use and maintain, and to operate in a standing position, the design of the hemp fiber separation machine that we developed was crucial. The design is illustrated in Fig. 1a. The frame of the constructed machine has a height of 75 cm and a base size of 75 x 65 cm. The part extending from the base has a height of 55 cm. Hemp fiber line set, with a mounting plate diameter of 22 cm, quantity 2 pieces, 1x1 inch angle iron, 3 mm thick, welded around the edge of the plate. Two types of blades were developed: a 0° blade angle (as shown in Fig. 1b) and a 15° blade angle (as shown in Fig. 1c). The blade angle (θ_e) critically influences cutting depth by affecting contact force and pressure. Larger angles reduce cutting efficiency, while abrasive wear further decreases pressure, leading to blunting below the required threshold (θ_e = 136 MPa). Optimizing θ_e and wear resistance is key to sustaining blade performance (Zhang et al., 2023). Including reducing peeling fatigue with a 1 hp motor. Transmit power using a 5” pulley to a 10” pulley. Wheels were installed for easy mobility.

(a) (b) (c)

Figure 1 This is the fiber separation machine: (a) Machine design (b) 0° blade angle (c) 15° blade angle

3. Testing the efficiency of the fiber separation machine

Testing the efficiency of the hemp fiber separator, the factors studied included (i) a set of feeds of 1, 2, and 3 stems, (ii) the distance between the fiber beat blade and a set of feeds set to 2 mm, (iii) the hemp stem samples were peeled at three blade speeds: 300, 400, and 500 rpm, with (iv) two blade angles of 0° and 15°, r (as shown in Fig.2).

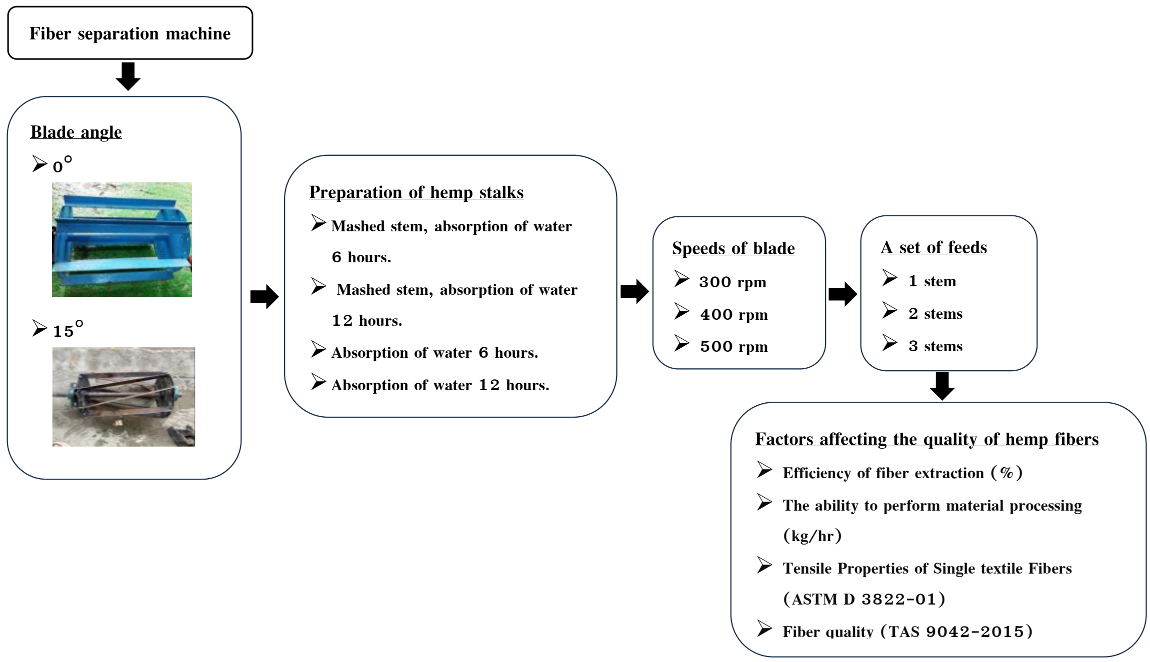

Figure 2 Flow chart of separate the fibers

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, and the loss after fiber separation is the weight of the core removed from the fiber relative to the total weight of the fiber, as Equations 2, 3, and 4, respectively (Chuan-Udom, 2013). As the machine is electric, the amount of electricity used in work also needed to be obtained. This was done using a multimeter (Luzino-digital clamp meter CAT III 600V), measuring the amount of electrical energy in volts and amps, and reactive power.

$$EF = \frac{A}{B} \times 100 \quad (2)$$

where EF = Efficiency of fiber separation machine (%), A = Length after fiber separation (cm), B = Length before fiber separation (cm) (Chuan-Udom, 2013).

$$C_m = \frac{M}{T} \quad (3)$$

where, C_m = Capability to perform material processing (kg/hr), M = The total weight of the materials feed into the machine (kg), T = Time of work (hour) (Chuan-Udom, 2013).

$$L = \frac{W_c}{W_t} \times 100 \quad (4)$$

where L = The loss after fiber separation (%), W_c = Weight of the core that has been stripped from the fiber (g), W_t = The total weight of the fiber (g) (Chuan-Udom, 2013).

4. Quality testing

The strength of the fibers was tested according to the standard method ASTM D 3822-01. The test for yarn tensile with 1 fiber per 2 to 3 meters in length was done by recording the breaking force of individual specimens to three significant digits as read directly from the tension testing machine (Single Column Tensile Strength Tester-M002C). The value obtained is the maximum force that the thread can withstand at the specified elongation (Specified elongation 5%) before breaking or being damaged. This was measured in centinewtons (cN), which is the standard unit for testing fibers and yarns. It is used to check if the yarn has sufficient resistance when stretched to a specified point, important in the production of yarn that does not require excessive stretching. Yarn tenacity is measured by Equation 5 (ASTM International, 2001).

$$Y = \frac{F}{D_L} \quad (5)$$

where Y = yarn tenacity (cN), F = force in strength (N), and D_L = linear length (c/tex) (ASTM International, 2001).

5. Statistical analysis

This study used appropriate statistical analyses (ANOVA, regression), with ANOVA used to test the differences in means between $\geq$ 2 groups. The factors in the test include preparation (A/B), absorption (hr), a set of feeds (stem), blade angle (degree), and speeds of the blade (rpm). To analyze the statistical differences of the testing factors, R^2 was calculated to measure the ability of data analysis (0 = poor, 1 = perfect). To find the Residuals to test the hypothesis of linear regression, normal distribution, mean close to zero, and homoscedasticity, were measured. Residuals with very high values (whether positive or negative) may be outliers that affect the model. Residuals are randomly distributed around zero without any pattern, indicating a good model. Residual analysis helps determine whether the model has flaws and how it should be improved to enhance the analysis results (Berman, n.d.).

Results and Discussion

1. Principle of the fiber separation machine

The hemp fiber separator uses power from a 1 hp motor. The power is transmitted to the 5" pulley and to the 10" pulley, with the blades angles set to 0° or 15° to separate the fibers from the bark and stem core (hemp peel). As described previously, and illustrated in Fig. 1a, 1b, and 1c, the fiber separation machine consists of 4 parts as follows; Part 1: The feeder for hemp stalks into the machine (Feeder) is set with a distance of 2 mm between the fiber comb and the feeder to ensure it is suitable for a set of feeds and the size of the hemp stalks. Part 2: Mechanism set for separating fibers from the bark and stem core. Part 3: The controller of the machine (Controller) is responsible for controlling the motor speed and cutting off the entire electrical circuit in case of an emergency. Part 4: The chamber for receiving bark and stem core residues serves to hold the remnants from the separation of fibers from the core and bark. The test with the optimal speed is at 400 rpm, with a set of feeds of 2 stems. Speed is a factor that affects the quality of the fiber. The characteristics of the obtained fibers as shown in Fig. 3a – 3h. The considerable variation in the capability of the steel blade suggests significant fluctuations in contact pressure, likely caused by dynamic interactions between the blade edge during a cut. This highlights the complex, unstable nature of the blade-paper contact, which influences cut performance (Zhang et al., 2023).

(a) After harvesting within 15 days (fresh)

(b) Dried hemp fiber, 0° blade angle

(c) Mashed stem, absorption of water 6 hours, 0° blade angle

(d) Non mashed stem, absorption of water 6 hours, 0° blade angle

(e) Mashed stem, absorption of water 12 hours, 0° blade angle

(f) Non mashed stem, absorption of water 12 hours, 0° blade angle

(g) Mashed stem, absorption of water 6 hours, 15° blade angle

(h) Non mashed stem, absorption of water 6 hours, 15° blade angle

Figure 3 Characteristics of hemp fibers separated using a fiber separator machine (speeds of blade400 rpm, a set of feeds 2 stems)

2. Efficiency of the fiber separation machine

The test results and statistical analysis in studying the factors affecting the machine performance include the preparation of hemp stalks, absorption of water, blade angle, a set of feeds, and speeds of the blade. Factors related to a set of feeds and speeds of the blade had no difference in machine performance. The regression analysis (R^2=0.96) confirms that hemp stalk preparation and water absorption significantly enhance fiber strength (p<0.05). However, feed rates and blade speeds show no significant impact (p>0.05). Optimal fiber strength requires focused attention on stalk preparation absorption of water, and blade angle. There, a comparison of electrical power usage was made. It was found that a set of feeds with 2 stems and a blade speed of 400 rpm used the least electrical power while still maintaining good performance and strong fibers. Therefore, a repeat test was conducted with a set of feeds, 2 stems, and blade speeds of 400 rpm to confirm the good results. Test separation of hemp fibers under the conditions following: Preparation of hemp stalks (A=mashed stem, B=non-mashed stem, 6=absorption of water 6 hours, 12=absorption of water 12 hours), factors of the fiber separation machine with blade angle and speeds of blade (1 5 = 1 5° blade angle, 0 = 0 ° blade angle). When comparing performance, standard deviation, and loss, it was found that 0 ° blade angle provides the highest efficiency (average 92-98%), loss of 0.8-5.6%. Mashed stems with a 15° angle have lower efficiency (averaging 55-88%) and higher loss compared to the 0° angle, which averages 13-40%. The 0° blade angle blade of standard deviation (SD) of 2.01 - 2.81. It is stable data, which has similar values. A 1 5 ° blade angle of SD of 6.90 and 7.88 has high variability, as shown in Fig. 4.

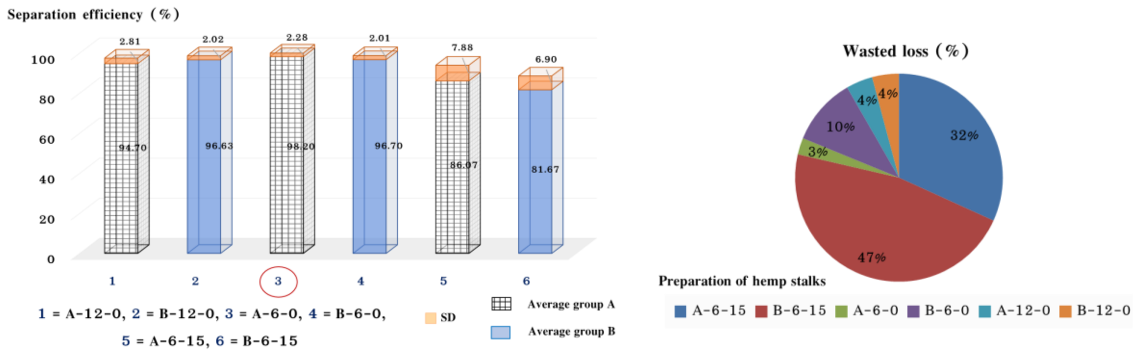

Figure 4 Separation efficiency and wasted loss with feed of 2 stems at a speed of 400 rpm (A=Mashed stem, B=Non mashed stem, 6=absorption of water 6 hours, 12= absorption of water 12 hours, 15=15° blade angle, 0=0° blade angle)

Table 2 shows Analysis of Variance of the efficiency of the fiber separation machine, indicating that the regression model is statistically significant with at least one variable, with an R^2 of 0.97. Table 3 shows the factors that affect the efficiency of the fiber separation machine. It was found that a change in the blade angle variable significantly affects fiber separation ($p < 0.05$) because our angle variation is still too small. For variables that do not affect the efficiency of the fiber separation machine, they are: preparation (A/B), absorption time (hr), a set of feeds (stem), speeds of blade (rpm), and significance level ($p < 0.05$). This is consistent with the research of Zhang et al. (2023), who stated that the critical cutting cycle number (N_C) decreases with increasing blade angle (θ), indicating that blades with higher angles blunt more easily. Due to its superior wear resistance, steel 9Cr18MoV consistently outperforms steel 5Cr15MoV, achieving higher NC values at the same blade angle. Once the cycle number (n) exceeds NC, cutting depth approaches a floor limit, with steel 5Cr15MoV degrading faster, highlighting the importance of material selection and blade angle optimization for sustained cutting performance (Zhang et al., 2023). Optimizing blade angles is essential for enhancing machining efficiency and quality, particularly for complex components. Our Research demonstrates that careful angle selection significantly improves process performance, though the optimal angle varies by application. Future studies should explore adaptive angle adjustment systems to maximize benefits across diverse machining scenarios.

Table 2 Analysis of variance (ANOVA) of the efficiency of the fiber separation machine

Source	df	SS	MS	F-value	Sig.
Regression	5	403,383.0714	80,676.61429	461.48	2.43836E-39
Residual	49	8,566.276059	174.8219604	-	-
Total	54	411,949.3475	-	-	-

Table 3 Coefficients of the variable, fiber separation machine

Variable	Coefficients	Standard deviation	p-value
Intercept	79.74	5.13	2.30E-20***
Preparation (A/B)	-1.59	1.48	0.288 ns
Absorption (hr)	-0.31	0.30	0.308ns
A set of feeds (stem)	-0.98	0.91	0.283ns
Blade angle (degree)	0.118	0.011	2.61E-14***
Speeds of blade (rpm)	-0.002	0.009	0.814ns

Note: ns = no significant (p > 0.05) difference, *, ** and *** = significant differences at p < 0.05, < 0.01 and < 0.001, respectively.

Table 4 shows that a stem preparation method significantly impacts fiber separation efficiency ($p < 0.05$), with mashed stem (group A) demonstrating superior performance compared to non-mashed stem (group B) ($p< 0.001$). While 12-hr water absorption yields significantly higher efficiency than 6-hr ($p<0.001$), the 6-hr duration remains operationally preferable as it reduce the time taken. The 0° blade angle provides significantly greater efficiency than the 15° angle ($p< 0.001$). A wider angle may help reduce fiber loss and increase strength. While feed rates and blade speeds show no significant impact ($p>0.05$). This does not affect the fiber separation efficiency, as all conditions use similar power (~0.4 kW). Multiple linear regression with 5 variables (as shown in Fig. 5) has statistically significant data variance with an R^2 of 0.83. The angle of the leaf strike is the only factor that affects the efficiency of hemp fiber separation under experimental conditions ($p< 0.001$). Adjusting the angle of the blade appropriately will help improve production efficiency, while other factors may not need to be changed under the current conditions. This is consistent with the research of Verho et al. (2025) whose algorithm, while showing limitations in determining precise fiber length distributions, provides reliable shape and orientation statistics. The power-law relationships shown between fiber length, shape factor, and orientation, that are likely influenced by pulp fiber rheology in polymer melts, offer valuable insights into biocomposite microstructure. This method serves as an effective foundation for reconstruction-based material modeling (Verho et al. 2025). Similar to Rahamaththulla et al. (2018), the rollers are essential for high-quality banana fiber extraction, outperforming saw tooth bars by preserving fiber integrity through optimized speed, angle, and clearance adjustments that maximize both yield and efficiency (Rahamaththulla et al., 2018). Fiber separation efficiency depends on a complex of fiber properties, characteristics, type of material, preparation, blade angle, a set of feeds, and speeds of the blade. Optimizing these interconnected factors enhances material performance and enables better design of fiber separation.

Table 4 Analysis of variance (ANOVA) and interactions between factors affecting the efficiency of hemp fiber separation

Factor	p-value
Preparation (A/B)	$< 0.001^{***}$
Absorption (6/12 hr.)	0.002^{*}
Blade angle (15°/0°)	$< 0.001^{***}$
Speeds of blade (rpm)	0.015^{**}
A set of feeds (stem)	0.120^{ns}
Interaction Effects	
Blade angle × Absorption	0.008^{*}
Blade angle × Preparation	0.001^{***}

Note: ns is no significant (p > 0.05) difference, *, ** and *** is significant differences at p < 0.05, < 0.01 and < 0.001, respectively.

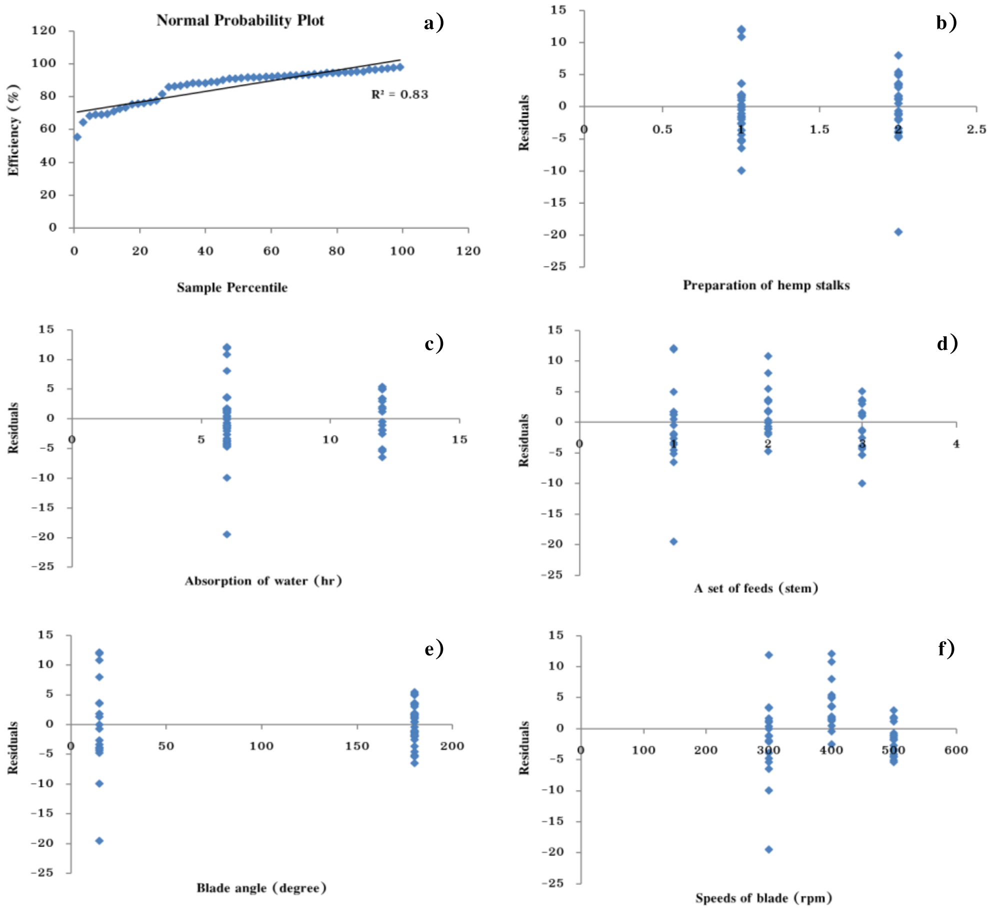

Figure 5 Multiple linear regression of the efficiency of hemp fiber separation between; a) normal probability plot, b) preparation of hemp stalks, c) absorption of water, d) a set of feeds, e) blade angle, f) speeds of blade

3. Strength of the fiber

The 0° blade provides high fiber strength (average 2,000–3,000 cN). A 15° blade provides lower strength (averaging 2,000–2,500 cN). The strength of the yarn is 6.711 cN, which was obtained from strength testing according to standard methods (ASTM International, 2007). When comparing the strength of hemp fibers to silk fibers, it was found that hemp fibers are strong enough to be used in textiles. Table 5 shows that the regression model has at least one variable affecting the strength of the fibers, as evidenced by an R^2 of 0.96. Preparation of hemp stalks of group A (mashed stem) yielded better results than group B (non-mashed stem), and absorption of water affected the strength of the fibers at a significant level ($p < 0.05$). A set of feeds (stem) and speeds of the blade (rpm) non-significant influence on the strength of the fibers at the significance level ($p < 0.05$). The change in the blade angle variable significantly affects fiber strength ($p < 0.05$). An increase in the blade angle by 1° will affect the strength of the fibers, which may cause the fibers to break and become inconsistent in size, as shown in Table 6. Multiple linear regression of the strength of fiber (as shown in Fig. 6) shows that the angle of the blade and the speed of the blade are the main factors affecting the strength of the fiber, with significance R^2 of 0.88. As the incomplete dispersion approaches 0, the residuals are randomly distributed and have no pattern (Berman, n.d.). Increasing the blade angle and higher speeds tends to improve the performance of blades could affect depending on the quality and strength of the fibers. Which is consistent with the research of Fidelis et al. (2013) stated that the tensile test results categorized the fibers into two distinct groups: high-performance (curauá, sisal, jute) and low-performance (coir, piassava). Among these, curauá fiber exhibited superior mechanical properties, with the highest Young's modulus (63.7 GPa) and tensile strength (543 MPa), making it the most promising for structural applications. This classification aids in selecting suitable natural fibers based on performance requirements. Karimah et al. (2021) Among the tested natural fibers, abaca exhibits the highest specific tensile strength combined with low density, making it an excellent lightweight yet strong material. Additionally, banana, jute, hemp, and pineapple fibers demonstrate superior specific toughness, with hemp achieving a remarkable tensile strength of 690 MPa. These findings highlight the potential of these natural fibers for applications requiring a balance of strength, toughness, and lightweight properties (Karimah et al., 2021). And consistent with the research of Thyavihalli Girijappa et al. (2019), chemical treatment optimizes natural fiber performance by reducing moisture absorption and enhancing matrix bonding, as demonstrated by hemp fibers achieving tensile strengths of 530-1,110 MPa after hemp fibers were treated with (3-glycidyloxypropyl) trimethoxy silane (Thyavihalli Girijappa et al., 2019). The strength of natural fibers is influenced by factors such as fiber morphology, chemical composition, and processing methods, with higher cellulose content and smaller fiber diameters generally leading to increased tensile strength.

Table 5 Analysis of variance (ANOVA) of strength of the fiber

Source	df	SS	MS	F-value	Sig.
Regression	5	279,987,768.3	55,997,553.66	264.13	1.08674E-33
Residual	49	10,388,329.7	212,006.73	-	-
Total	54	290,376,098	-	-	-

Table 6 Coefficients of the variable, strength of the fiber

Variable	Coefficients	Standard deviation	p-value
Intercept	2210.56	301.28	2.24E-09*
Preparation (A/B)	286.04	86.93	0.00188*
Absorption (hr)	-57.58	17.74	0.00214*
A set of feeds (stem)	-5.42	53.23	0.919ns
Blade angle (degree)	1.15	0.65	0.08ns
Speeds of blade (rpm)	-0.055	0.53	0.919 ns

Note: ns is no significant ($p > 0.05$) difference, *, ** and *** is significant differences at $p < 0.05$, < 0.01 and < 0.001, respectively.

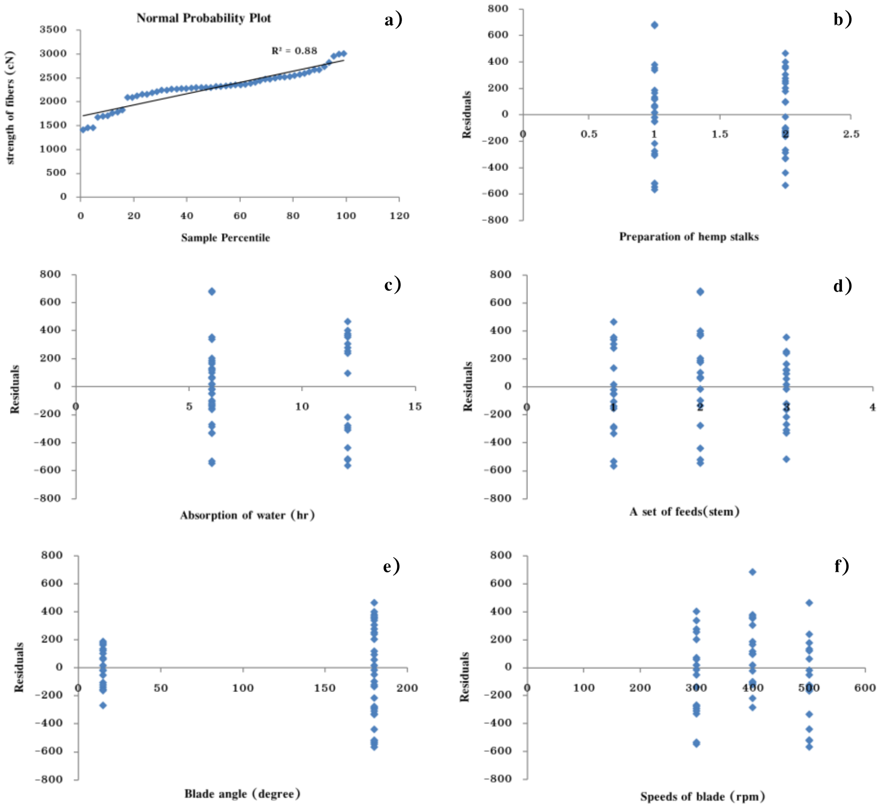

Figure 6 Multiple linear regression of the strength fiber between: a) normal probability plot, b) preparation of hemp stalks, c) absorption of water, d) a set of feeds, e) blade angle, f) speeds of blades

Factors affecting the separation of hemp fibers using a machine include the preparation of hemp stalks, the speed of the blade, and the set of feeds. The resulting fibers will be strong, and the machine can operate efficiently. The blade angle has very little effect on the quality of the fiber. Since the change in the blade angle is too minimal. However, using a machine for fiber separation will make it much more convenient for farmers and reduce the time required for the task. But the use of the machine still has technical limitations. If the speed or impact force is not set properly from the blade angle, it may cause the fibers to break or get damaged, affecting the quality of the fibers. Including the need to prepare the stem before conducting the test. To make the fiber separation more efficient.

Conclusion and Suggestions

The separation and use of natural fibers reduces agricultural waste. The production of natural fibers involves peeling the hemp (dry) bark using a fiber separation machine, should be preceded by preparing the stems by pounding or smashing them. The prepared stems are then soaked in water for 6 hr, at which time the moisture level of the stems is closest to the 15-day post-harvest moisture content. The fibers are separated with a blade angle of 0°, where the blade angle significantly affects the depth of the beat. Depending on the contact force and the wide blade angle, it would reduce the peel efficiency. A 15° blade angle has low efficiency and does not vary much when the absorption time changes. The optimal speed is 400 rpm, with a set of feeds of 2 stems, a capacity of 5.52 kg/hr. The separation efficiency is 98.20%, the post-separation loss is 0.98%, and it uses 0.40 kW of electrical power. The average fiber strength of the hemp is 3,008.83 cN compared to the yarn strength of 6.711 cN. Processing 33 kg/day, at 30 baht/kg selling price, daily income will be 990 baht, giving an annual income of 89,100 baht. When considering a work schedule of 90 days per year, the average annual net profit will be 53,672.04 baht. Therefore, the payback period for the fiber separation machine is approximately 1.5 months or about 40 days. Hemp fibers are natural fibers that are durable and have good elasticity. The hemp fiber separator is easy to use, and operators do not need any special skills. Reduce work fatigue and shorten the drying time of hemp stem (peel and fiber grind). It produces fibers with strength suitable for use in textiles. To achieve better efficiency, the set of feeds can be increased by adjusting the distance between the fiber beat blades and the feed area. The characteristics of other blade shapes that are suitable for fiber separation should mbe investigated, so they can be used with other types of natural fiber plants. In future studies, it is recommended to develop a machine that integrates the working system in the same production line for raw material feeding and fiber sorting. The separation of fibers with machines will yield high-quality fibers sufficient to supply the future demands of the textile industry.

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Author Contributions

Author 1 (Rewat Termkla): Study conceptualization, methodology design, research, and manuscript writing.
Author 2 (Ruttanachira Ruttanaprasert): Methodology design and data interpretation.
Author 3 (Ratanarekha Atchariyapitak): Methodology design and data interpretation.
Author 4 (Kiartiphum Duangsri): Providing materials subjects and collection of data.
Author 5 (Arunsak Boonphum): Development, providing materials subjects, collection of data, and analysis.
Author 6 (Lakkana Pitak): Conceptualization, methodology design, data interpretation and analysis, research, manuscript writing, review, and editing.

Conflict of Interests

The authors declare that he has no conflicts of interest.

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