EXPERIMENTAL INVESTIGATION OF TECHNOLOGICAL FACTORS INFLUENCING LOTUS SILK FIBER LENGTH DURING THE EXTRACTION–DRAWING PROCESS

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Abstract - Lotus silk is a natural fiber with high economic value; however, current production remains largely manual, resulting in low productivity and limited scalability. This study experimentally investigates the length of lotus fibers drawn under the influence of processing parameters, including storage time, lotus stem diameter, cutting depth, and the length of the lotus stem segment involved in the extracting process. Experiments were conducted with 108 combinations, and the data were analyzed using analysis of variance (ANOVA). The results indicate that the effective extracted stem length is the dominant factor influencing fiber length, followed by post-harvest time and stem diameter. The interactions between post-harvest time × stem diameter and cutting depth × post-harvest time were found to have significant effects. Furthermore, the lotus silk yield reached 102.4 mg per kg of fresh lotus stems. These findings provide an initial quantitative basis for the development of mechanized solutions for the lotus silk extraction process.

Key words - Lotus silk; extraction and drawing process; fiber length; technological parameters

1. Introduction

Lotus (Nelumbo nucifera) is an aquatic plant widely cultivated in Asia, and the Mekong Delta is one of the major lotus-growing regions in Vietnam [1, 2]. In addition to traditional products, lotus stems serve as a raw material for lotus silk production, which is a high-value natural fiber with strong potential for sustainable textiles [3, 4]. Lotus silk, extracted from the mucilaginous layer inside the lotus stem and used for weaving fabric since the early twentieth century in Myanmar, is highly valued for its superior functional and ecological properties [5, 6]. The manual production process, which does not use toxic chemicals, also makes lotus silk a valuable eco-friendly material in the context of sustainable development. In addition, previous studies on lotus-based processing, particularly in the mechanization of lotus seed processing, suggest that these efforts still demonstrate the potential for improving productivity and reducing labor dependence in lotus-based processing in general [7, 8].

At present, lotus silk production remains predominantly manual. Fiber extraction and yarn twisting are performed entirely by hand, dependence on seasonal raw materials, low productivity, and high labor costs, and therefore has not yet been developed on an industrial scale [9, 10]. In Vietnam, lotus stems are the main raw material for lotus silk production, but most of them have not been effectively utilized after harvest because the manual production process requires a large quantity of lotus stems and prolonged labor time to produce lotus silk [11], resulting in high costs, limited scalability, and an urgent need to improve the efficiency of fiber extraction and drawing.

Current research on lotus silk has mainly focused on material properties and applications, whereas the technological factors governing the extraction and drawing of fibers from lotus stems have not been systematically analyzed [12-15]. In particular, the technological parameters and geometric characteristics of lotus stems, including diameter, storage time, cutting depth, and the length of the segment involved in drawing, as well as the fiber drawing length, have not yet been clearly determined, creating difficulties for process standardization. Therefore, this study aims to systematically investigate the factors affecting the extraction–drawing length of lotus silk fibers from lotus stems, thus providing a scientific basis for process improvement and the design of supporting equipment, with two specific objectives: (i) to evaluate the effects of selected technological parameters and geometric characteristics on fiber length, and (ii) to clarify the empirical relationships between the technological parameters and the drawing length of lotus silk fibers.

The main contributions of this study are as follows: (i) to provide an initial experimental dataset on the effects of technological factors on the spinnability of lotus silk fibers; (ii) to clarify the quantitative relationships among lotus stem characteristics, fiber-drawing conditions, and the obtained fiber length; and (iii) to provide orientation for the future development of mechanized solutions for the lotus silk spinning process. These findings are expected to help narrow the current research gap and establish a scientific foundation for improving productivity and scalability in lotus silk production in Vietnam.

2. Methodology

2.1. Preparation of lotus stems

The lotus stem treatment procedure prior to fiber extraction and drawing was carried out in sequential steps, as illustrated in Figure 1, to ensure the uniformity of the experimental samples and the fiber-forming capability during the extraction–drawing process. Lotus stems were harvested at an appropriate growth stage, cut into segments, and processed mainly manually. The raw material was then cleaned to remove impurities adhering to the surface, similar to pretreatment steps in plant fiber production, thereby improving spinnability and uniformity.

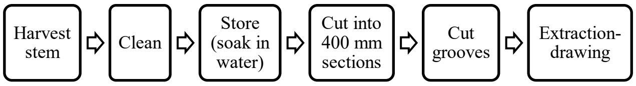


Figure 1. *Lotus stem processing procedure*

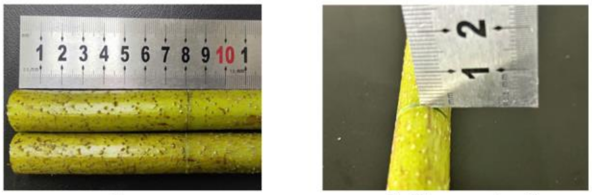
The extraction–drawing process was performed in sequential steps to ensure continuous and stable fiber formation. First, the harvested lotus stems were stripped of thorns and excess tissue, and then cut into segments with lengths of 400–500 mm to ensure uniformity and suitability for subsequent processing operations (Figure 2a). The lotus stems were then cleaned of impurities and soaked in water to maintain freshness, limit resin drying, and preserve fiber-forming capability (Figure 2b).

Next, a groove with a specified depth (1–2 mm) and appropriate length (20–80 mm) was created on each segment to separate the rigid outer layer and facilitate fiber drawing (Figure 2c). After groove cutting, the lotus stem was placed into the drawing mechanism, where a tensile force was applied along the stem axis to carry out fiber extraction and drawing.

The tensile force required to separate the lotus stem into two parts varied among the experimental cases. However, investigating the effect of tensile force was not an objective of this study; therefore, this parameter was fixed at a sufficiently high value to ensure specimen rupture in all cases. The lotus stem sample expected to require the greatest tensile force, corresponding to the largest diameter C (15 mm), the smallest groove depth D (1 mm), and the longest storage time T (36 h), was selected and tested five times. After confirming that this tensile force met the requirement, the value was fixed for all experimental samples, as presented in Table 2.

The quality of the fibers was evaluated through indicators such as uniformity, length, and continuity. These results served as the basis for fiber selection and preparation for subsequent spinning and processing stages.

a) Cut into 40 cm *b) Soak in water*

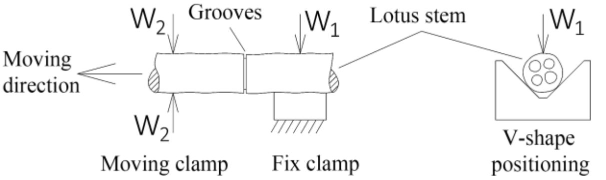


c) Cut grooves *d) Groove depth*

Figure 2. *Lotus stem treatment prior to silk extraction–drawing*

2.2. Method and experimental setup for lotus silk fiber extraction–drawing

The schematic diagram of the lotus silk extraction–drawing experiment and the experimental model are presented in Figures 3 and 4, respectively. First, the lotus stem was clamped at both ends by the movable clamp W1 and the fixed clamp W2 (Figure 3a), and the approximately cylindrical shape of the stem was positioned in the V-shaped groove, as shown in Figure 3b. Then, the stepper motor, through the lead screw shaft, generated rotational motion, causing the movable clamp together with the firmly clamped lotus stem section to move away from the stem section held by the fixed clamp. The resulting axial tensile force acted on the lotus stem and was concentrated at the groove position (Figures 3a and 5), stretching the tissue structure and drawing the fiber bundles away from the soft tissue, thereby forming and obtaining lotus silk. The extraction–drawing process was visually observed and monitored until completion, and the fiber drawing length of the lotus silk was recorded using a ruler fixed to the frame of the experimental apparatus (Figure 6).



a) Front view *b) Side view*

Figure 3. *Schematic diagram of the lotus silk extraction–drawing experiment*

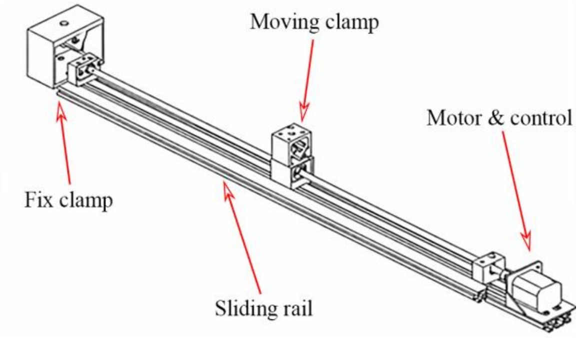


Figure 4. *Experimental model for lotus silk fiber extraction–drawing*

A depth-controlled cutting blade set was used to cut grooves on the lotus stems during the experiment. The cutting blade was firmly clamped by two holding plates, and the gap between the blade and the surface of the holding plate was adjustable (Figure 5a). During cutting, the lotus stem was placed on a flat surface, and the blade set was rolled and pressed over a sufficient distance to ensure that the entire circumference of the stem was cut (Figure 5b).

a) Cutting groove knife *b) Cut grooves*

Figure 5. *Cutting grooves in lotus stems with a cutting knife*

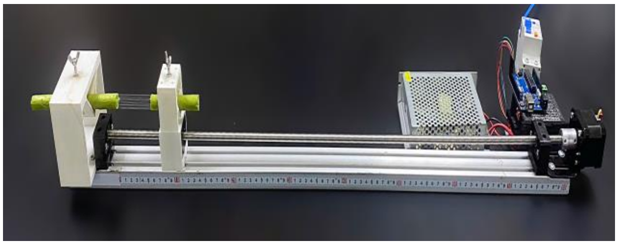


Figure 6. *Experimental model for lotus silk extraction–drawing*

2.3. Evaluation of lotus silk fiber yield

To evaluate fiber yield, fresh lotus stems after harvest were subjected to extraction–drawing manually, independently of the extraction–drawing system using the experimental apparatus described in Section 2.2. Before drawing, the lotus stems were cleaned and stripped of thorns and impurities. The extraction–drawing process was performed according to the experience of the worker within 1 hour after harvest to ensure the freshness of the stem resin. During drawing, the silk fibers were continuously collected and bundled for mass measurement. The manual method was selected for yield evaluation because the automatic extraction–drawing system has not yet been completed and is not yet suitable for use in the experiment.

The length of the lotus stem segment involved in drawing was fixed at L = 40 mm in the yield evaluation experiment to represent an average operating condition within the investigated range.

The mass of the dried silk fibers, which was very small, was measured using an Ohaus PR224/E analytical balance (capacity: 220 g, readability: 0.1 mg), whereas the initial mass of the lotus stems was determined using an Ohaus NV2202 balance (capacity: 2,200 g, readability: 10 mg). The fiber extraction yield was calculated based on the ratio between the mass of the obtained silk fibers and the initial mass of the lotus stems.

2.4. Analysis of the effects of technological parameters on lotus silk fiber length

To conduct this analysis, lotus stems were harvested and prepared as described in Section 2.1. The experiment was carried out using the setup presented in Section 2.2. The lotus stem segment was mounted between the two clamps, after which the motor moved the movable clamp to perform lotus silk extraction–drawing.

The fiber state was continuously monitored, and the fiber length was measured directly using the ruler mounted along the sliding rail (Figure 6). During the experiment, the formation and elongation states of the fibers were visually observed. The drawing process was continued until fiber breakage began to appear; at which point, the movement of the movable clamp was stopped, and the fiber length was determined at the break point.

Table 1. *Drawing length and error at different speeds.*

	Extracting speed (mm/s)					
	10	15	20	25	30	40
Mean extracting length (mm)	575.3	567.4	572.1	543.0	555.0	555.7
SD (mm)	45.5	44.9	50.5	58.9	60.4	56.3

Because the evaluation method was based on manual observation, the drawing speed had a substantial influence on result reading and caused deviations in fiber length determination. The experiment to determine an appropriate drawing speed was conducted at levels of 10, 15, 20, 25, 30, and 40 mm/s, with seven repetitions at each level (42 samples in total), under the following conditions: T = 0 h; C = 11–13 mm; D = 1,5 mm; L = 40 mm. The results showed that the standard deviation remained nearly unchanged in the range of 25–40 mm/s (SD ≈ 58.9 mm), decreased markedly at 20 mm/s (SD ≈ 50.5 mm) and only decreased slightly at lower speeds (SD ≈ 45.5 mm). Therefore, the speed of 20 mm/s was selected for the subsequent experiments to reduce observation error while ensuring a reasonable experimental duration.

The technological factors considered included post-harvest storage time (T), lotus stem diameter (C), groove cutting depth (D) and the length of the lotus stem segment involved in extraction–drawing (L). The investigated ranges are described in detail in Table 2. The drawing speed was kept constant at 20 mm/s to eliminate deviations caused by speed variation. In addition, the speed was selected at a low level to ensure the ability to observe and measure fiber length.

Table 2. *Investigated ranges of technological parameters*

Parameter	**Symbol**	**No. of levels**	**Investigated range**
Storage time	T	3	12; 24 and 36 hour
Stem diameter	C	3	9–11; 11–13 and 13–15 mm
Depth of groove	D	3	1; 1.5 and 2 mm
Extracted length of stem	L	4	20; 40; 60 and 80 mm

The combination of factor levels generated 108 experimental combinations. The fiber length value used for ANOVA was taken as the mean of five measurements to represent the result of each experimental combination and to reduce the influence of random fluctuations among repetitions. The experimental data were processed using Minitab software through analysis of variance (ANOVA) to determine the degree of influence and statistical significance of each parameter as well as their interactions [16-18].

3. Results and discussion

3.1. Lotus silk extraction–drawing yield

Lotus silk was extracted manually by the extraction–drawing method from 2,042.8 g of fresh lotus stems. Each stem segment was drawn only once, with the length of the segment involved in drawing fixed at 40 mm. The measured mass of lotus silk reached 209.2 mg, corresponding to an average yield of approximately 102.4 mg of lotus silk obtained from 1 kg of fresh lotus stem material.

3.2. Effects of individual parameters

The results of the one-way analysis of variance (one-way ANOVA) and the main effects plot are presented in Table 3 and Figure 7, respectively. Accordingly, the regression model was statistically significant (P = 0.004) and explained 99.4% of the total variation in the data.

Table 3. *Results of one-way ANOVA*

Source	DF	Seq SS	Con (%)	Adj SS	Adj MS	F-Value	P-Value
Model	101	7,934	99.4	7,934	78.6	9.40	0.004
Linear	9	4,662	58.4	4,663	518.1	61.98	0.000
D	2	177	2.2	177	88.42	10.58	0.011
T	2	250	3.1	250	124.9	14.94	0.005
L	3	4,058	50.8	4,058	1,352.6	161.8	< 0.001
C	2	178	2.2	178	89.1	10.66	0.011

The linear effects group contributed 58.4% of the total variation. Specifically:

- The length of the lotus stem segment used for fiber extraction (L) had the largest contribution (50.8%), with $F = 161.8$ and $P < 0.001$.
- Post-harvest storage time (T) contributed 3.1% ($P = 0.005$).
- Groove cutting depth (D) contributed 2.2% ($P = 0.011$).
- Lotus stem diameter (C) contributed 2.2% ($P = 0.011$).
- The order of decreasing influence was: $L > T > C \approx D$.

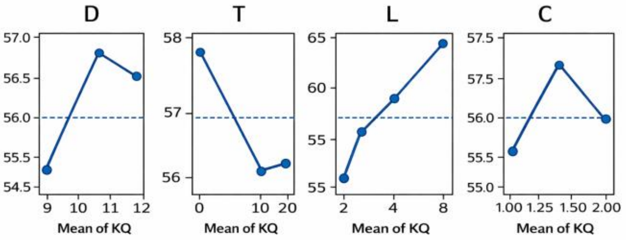


Figure 7. *Main effects plot*

3.3. Results of two-parameter interaction analysis

The results of the two-way analysis of variance (two-way ANOVA) are presented in Table 4 and Figure 8. The two-parameter interaction group contributed 15.5% of the total variation in lotus silk fiber length and was statistically significant ($P = 0.016$).

Table 4. *Results of two-way ANOVA*

Source	DF	Seq SS	Con (%)	Adj SS	Adj MS	F-Value	P-Value
2-Way	24	1,237	15.5	1,237	51.5	6.17	0.016
D×T	4	404	5.1	403	100.9	12.07	0.005
D×L	6	1,334	1.7	133	22.3	2.67	0.129
D×C	4	112	1.4	112	28.0	3.35	0.091
T×C	4	501	6.3	501	125.0	14.97	0.003
L×C	6	87	1.1	87	14.5	1.73	0.260

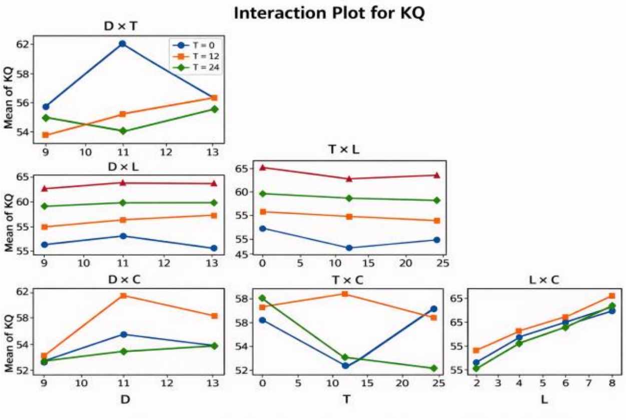


Figure 8. *Interactions between parameter pairs*

Among the investigated interaction pairs, two pairs showed statistical significance:

- T×C: contribution of 6.3%, $F = 14.97$, $P = 0.003$ (representing the largest interaction effect).
- D×T: contribution of 5.1%, $F = 12.07$, $P = 0.005$.
- The remaining three interaction pairs, including D×L ($P = 0.129$), D×C ($P = 0.091$) and L×C ($P = 0.260$) were not statistically significant and had low contribution rates (1.1–1.7%).
- In terms of contribution level, the interaction effects decreased in the following order: $T\times C > D\times T \gg D\times L \approx D\times C \approx L\times C$.

3.4. Effects of higher-order interactions

The results of the analysis of variance for the three- and four-parameter interactions are presented in Table 5. The higher-order interaction group accounted for a considerable proportion of the total variation in lotus silk fiber length, indicating the simultaneous involvement of multiple technological parameters in the fiber-drawing process.

Three-parameter interactions (3-way)

The total three-parameter interaction group had 44 degrees of freedom (DF) and contributed 14.1% of the total variation. However, when considered as a whole, this group did not reach statistical significance, with $P = 0.080$.

When each combination was analyzed separately, two combinations were statistically significant ($P < 0,05$):

- D×L×C had the largest contribution (5.5%), with $F = 4.40$, $P = 0.040$;
- D×T×C contributed 3.6%, with $F = 4.27$, $P = 0.047$.

The remaining combinations were not statistically significant and had lower contribution levels, including:

- D×T×L: 1.8% ($P = 0.352$);
- T×L×C: 3.3% ($P = 0.124$).

In general, the influence levels among the three-parameter interactions were clearly differentiated, and only certain specific combinations exhibited significant effects.

Four-parameter interaction (4-way)

For the four-parameter interaction, the combination D×T×L×C had 24 degrees of freedom, contributed 11.3% of the total variation, and was statistically significant ($F = 4.51$; $P = 0.034$). The contribution of this combination was higher than that of each individual three-parameter interaction.

Table 5. *Results of three-way and four-way ANOVA*

Source	DF	Seq SS	Con (%)	Adj SS	Adj MS	F-Value	P-Value
3-Way	44	1,130	14.1	1.130	25.7	3.07	0.080
D×T×L	12	141	1.8	141	11.7	1.41	0.352
D×T×C	8	285	3.6	286	35.7	4.27	0.047
D×L×C	12	442	5.5	442	36.8	4.40	0.040
T×L×C	12	262	3.3	262	21.8	2.61	0.124
4-Way	24	905	11.3	905	37.7	4.51	0.034
D×T×L×C	24	905	11.3	905	37.7	4.51	0.034
Error	6	50	0.6	50	8.4		
Total	107	7,984	100				

3.5. Regression model

The second-order polynomial regression equation expressing the relationship between the parameters and the objective function was constructed as follows:

$$\begin{aligned}KQ &= 194.0 - 15.48D + 5,96L - 672c + 0.4758T^2 \\ &+280.5c^2 - 3.105DT + 106.0Dc + 21.34Tc - 3.91Lc \\ &+0.1972D^2T - 3.804.D^2c - 45.1Dc^2 - 0.575T^2c \\ &-0.01350T.L^2 - 9.24Tc^2 - 0.000362D^2T^2 \\ &-0.0632D^2.T.c + 1.695D^2c^2 + 0.426D.T.c^2 \\ &+0.0967.D.L.c^2 + 0.1844T^2c^2 + 0.00933TL^2c\end{aligned} \tag{1}$$

The results indicate that the relationships among the factors were nonlinear and involved complex interactions. The inclusion of terms such as T^2, C^2, D×T, D×C, T×C and higher-order combinations allowed the model to adequately reflect both the individual and combined effects of the variables on the response value KQ.

The model fit evaluation results presented in Table 6 show that the coefficient of determination R^2 reached 74.57%, meaning that the model explained approximately 74.57% of the variation in the dependent variable. After adjustment for the number of variables, the adjusted R^2 was 67.98%, still indicating relatively good explanatory ability. However, the predicted R^2 was 58.09%, which was substantially lower than R^2 and adjusted R^2, suggesting that the predictive ability of the model was moderate and that overfitting may exist due to the relatively large number of variables and interaction terms. The standard error of the model, S = 4.89 reflects that the dispersion of the residuals around the predicted values was not excessively large. The criteria AICc = 685.82 and BIC = 735.73 can be used for comparison with alternative models; a model with smaller AICc and BIC values would be preferred.

***Table 6.** Errors in constructing the second-order regression model*

S	R^2 (%)	Adj. R^2 (%)	PRESS	Pred. R^2 (%)	AICc	BIC
4.89	74.57	67.98	3,346.55	58.09	685.82	735.73

Analysis of the variation trend of the parameters showed that when L increased from the lower limit to the upper limit, fiber length increased markedly and reached its maximum value at approximately L ≈ 80 mm, indicating that L was the most dominant factor affecting the objective function. For parameter C, fiber length increased slightly as lotus stem diameter increased and reached its best value within the range of approximately C ≈ 13–15 mm. In contrast, when T increased from the harvest time to later time points, fiber length tended to decrease due to the degradation of the mechanical properties of the conductive tissue; therefore, the optimal value was achieved at T < 12 h after harvest. For D, fiber length reached its maximum at the intermediate level of approximately D ≈ 1.5 mm, whereas cutting too shallowly or too deeply both reduced drawing efficiency.

Based on the above results, the optimal set of technological parameters within the investigated conditions was identified as approximately D ≈ 1.5 mm, T < 12 h, L ≈ 80 mm and C ≈ 13–15 mm, at which the model predicted the maximum fiber length.

4. Discussion

The experimental results showed that the recovery yield of lotus silk reached 102.4 mg/kg of fresh stems, reflecting the relatively low fiber density in lotus stem tissue and indicating that the extraction–drawing process requires a large amount of raw material to achieve a substantial output. This emphasizes the need of optimizing the technological parameters to improve extraction efficiency.

ANOVA identified the length of the lotus stem segment involved in drawing (L) as the dominant parameter, contributing 50.8% of the total variation, far exceeding the other parameters. This result is consistent with the regression coefficients of the model, in which L had the largest effect coefficient among the linear and quadratic components, indicating that the length of the segment involved in extraction–drawing is the determining factor governing the ability to form and maintain fiber continuity. This conclusion is consistent with studies on fiber extraction from plant materials such as banana, ramie, or flax, in which the length of the mechanically treated zone is often reported as the most important parameter determining fiber continuity.

The parameters of post-harvest time (T), stem diameter (C) and cutting depth (D) exhibited smaller effects but were still statistically significant. The reduction in fiber length with increasing storage time may be related to physico-chemical changes in plant tissue after harvest; however, this mechanism was not verified within the scope of the present study. Although cutting depth had a limited individual effect, it appeared in several significant interactions, indicating its role in adjusting the mechanical contact conditions during the fiber-drawing process.

Comparison among interaction orders showed that the two-parameter interaction group contributed the largest proportion of variation (15.5%), higher than the three-parameter group (14.1%) and the four-parameter group (11.3%). This result follows a similar trend of the regression equation, in which the two-variable interaction terms dominated in describing the response trend, whereas the higher-order interactions only played a role in local adjustment. Therefore, process optimization should prioritize controlling the main effects and important interaction pairs such as T×C and D×T, rather than more complex higher-order combinations within the current data range.

Based on the main effects and the statistically significant interactions, a technological parameter region tending to produce greater fiber length within the investigated range can be identified, including: post-harvest time of less than 12 h, lotus stem diameter of 13–15 mm, cutting depth of 1.5 mm, and lotus stem segment length involved in drawing of 80 mm. This parameter region can be considered as a reference operating condition for the lotus silk drawing process within the scope of the conducted experiments.

However, the study still has several limitations, including the low degrees of freedom of the error term; the fact that the extraction–drawing process for yield evaluation was still performed manually, making operational errors difficult to avoid; and the limited investigated range of parameter levels, which focused only on the fiber length criterion. In future studies, the parameter range should be expanded, the number of repetitions should be increased, and a semi-automatic or mechanically controlled drawing system should be developed to reduce human-induced variation. At the same time, additional evaluation of the mechanical and morphological characteristics of the fibers should be conducted, and the effect of drawing speed should also be investigated to improve the modeling of the fiber extraction–drawing process.

5. Conclusion

This study systematically evaluated the effects of technological parameters on the extraction–drawing process of lotus silk fibers from lotus stems. The fiber recovery yield reached 102.4 mg/kg of fresh raw material, reflecting the characteristics of fiber extraction from natural plant-based materials. The analysis of variance model showed that the overall model was statistically significant at the 95% confidence level ($P < 0,05$), with a coefficient of determination of $R^2 = 74.57\%$ and an adjusted coefficient of determination of $R^2 = 67.98\%$, indicating that the model explained most of the variation in the experimental data. The predicted coefficient of determination of 58.09% indicated an acceptable predictive capability within the investigated range.

Based on these results, the ANOVA identified the length of the lotus stem segment involved in drawing (L) as the dominant parameter, contributing 50.8% of the total variation in fiber length. The parameters of post-harvest time (T), stem diameter (C) and cutting depth (D) had smaller contributions but still reached statistical significance ($P < 0.05$). The two-parameter interactions, particularly T×C and D×T, showed considerable effects on fiber length, whereas the higher-order interactions had smaller contributions and limited influence within the current model range.

In addition to the analysis of variance, a polynomial regression model based on the response surface methodology (RSM) was developed to quantitatively describe the relationship between fiber length and the parameters D, T, L, C, including linear, quadratic, and interaction terms. The regression results and contour plots were consistent with the ANOVA, and also allowed the identification of a reference operating parameter region for achieving the maximum fiber length within the investigated range ($T < 12$ h, $C = 13–15$ mm, $D = 1.5$ mm, $L = 80$ mm), thereby providing a scientific basis for the optimization and mechanization of the lotus silk drawing process.

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REFERENCES

[1] P. K. Mukherjee, D. Mukherjee, A. K. Maji, S. Rai, and M. Heinrich, "The sacred lotus (Nelumbo nucifera)– phytochemical and therapeutic profile," *Journal of Pharmacy and Pharmacology,* vol. 61, no. 4, pp. 407-422, 2009. https://doi.org/10.1211/jpp.61.04.0001

[2] Z. Lin, C. Zhang, D. Cao, R. N. Damaris, and P. Yang, "The Latest Studies on Lotus (Nelumbo nucifera)-an Emerging Horticultural Model Plant," *International Journal of Molecular Sciences,* vol. 20, no. 15, art. 3680, 2019. https://doi.org/10.3390/ijms20153680

[3] A. Mohanty, M. Misra, L. Drzal, S. Selke, B. Harte, and G. Hinrichsen, *Natural Fibers, Biopolymers, And Biocomposites*. Boca Raton, FL, USA: CRC Press, Taylor & Francis Group, 2005. https://doi.org/10.1201/9780203508206

[4] X. H. Yuan, Y. J. Gan, D. S. Chen, and Y. J. Ye, "Analysis on Mechanical Properties of Lotus Fibers," *Advanced Materials Research,* vol. 476-478, pp. 1905-1909, 2012. https://doi.org/10.4028/www.scientific.net/AMR.476-478.1905

[5] T. P. Sathishkumar, P. Navaneethakrishnan, S. Shankar, R. Rajasekar, and N. Rajini, "Characterization of natural fiber and composites – A review," *Journal of Reinforced Plastics and Composites,* vol. 32, pp. 1457–1476, 2013. https://doi.org/10.1177/0731684413495322

[6] M. Yusuf, D. Sharma, M. Khan, S. Syed, S. Mian, and M. Asif, "Overview of lotus fiber: Types, sustainable properties and eco-friendly aspects," *International Journal of Pharmaceutical Sciences and Innovations,* vol. 4, no. 2, pp. 8-16, 2024.

[7] L. A. Van, V. D. Dinh, M. D. Hung, N. H. Tam, and L. D Nhon, “Design, Fabrication, and Performance Evaluation of a Fresh Lotus Seed Shelling Machine Incorporating Lifting Cam and Automatic Compression Spring Mechanisms”, *The University of Danang - Journal of Science and Technology*, vol. 23, No. 11, pp. 60-65, 2025. https://doi.org/10.31130/ud-jst.2025.23(11).210

[8] H. T. Thuong, N. V. Cuong, L. P. Hung, N. H. Tan, H. Q. Khanh, and N. V. Tai, “Research on the Classification Method of the Rice and Seed Shell Parts of Fresh Lotus”, *The University of Danang - Journal of Science and Technology*, vol. 21, No. 3, pp. 27-32, 2023. https://jst-ud.vn/jst-ud/article/view/8258

[9] N. Van-Tinh, N. Ngoc-Kien, and B. Ngoc-Tam, "Fabrication of Lotus Fibre Spinning Machine," *International Journal of Engineering and Technology,* vol. 16, pp. 16-19, 2024. https://doi.org/10.7763/ijet.2024.v16.1248

[10] R. Pandey, A. Dubey, and M. K. Sinha, *Lotus fibre drawing and characterization*, in *Sustainable Fibres for Fashion and Textile Manufacturing*, Cambridge, Massachusetts, USA: Woodhead Publishing, 2023. https://doi.org/10.1016/B978-0-12-824052-6.00001-9

[11] S. Aishwariya and S. Thamima, "Sustainable textiles from lotus," *Asian Textile Journal,* vol. 28, no. 10, pp. 56-59, 2019.

[12] N.-K. Nguyen and V.-T. Nguyen, "A prototype of lotus fiber extracting machine", in *International Conference on Engineering Research and Applications, Cham*, Springer International Publishing, pp. 65-73. https://doi.org/10.1007/978-3-031-22200-9_7

[13] N.-K. Nguyen and V.-T. Nguyen, "Design and manufacturability data of automatic lotus fiber extractor," *Data in Brief,* vol. 53, p. 110175, 2024. https://doi.org/10.1016/j.dib.2024.110175

[14] C. Cheng, R. Guo, J. Lan, and S. Jiang, "Extraction of lotus fibres from lotus stems under microwave irradiation," *Royal Society Open Science,* vol. 4, no. 9, art. 170747, 2017. http://doi.org/10.1098/rsos.170747

[15] D. S. Chen, Y. J. Gan, and X. H. Yuan, "Research on Structure and Properties of Lotus Fibers," *Advanced Materials Research,* vol. 476-478, pp. 1948-1954, 2012. https://doi.org/10.4028/www.scientific.net/AMR.476-478.1948

[16] S. Atoui, A. Belaadi, M. Boumaaza, I. M. H. Alshaikh, and D. Ghernaout, "Weibull Statistics and ANOVA Analysis of the Tensile Mechanical Characteristics of Chamaerops humilis Cellulose Fibers and Sustainable Twisted Yarns," *Journal of Natural Fibers,* vol. 21, no. 1, p. 2431677, 2024. https://doi.org/10.1080/15440478.2024.2431677

[17] R. A. Fisher, *Statistical methods for research workers, 11th ed. rev* (Statistical methods for research workers, 11th ed. rev.). Oliver and Boyd: Edinburgh, 1925.

[18] M. H. Herzog, G. Francis, and A. Clarke, *Understanding Statistics and Experimental Design: How to Not Lie with Statistics*. Cham, Switzerland: Springer International Publishing, 2019. https://doi.org/10.1007/978-3-030-03499-3