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# A double blade splitting machine for *Cyperus* sedge culms (*Cyperus corymbosus* Rottb.)

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**Abstract**

Sedges are a natural material that can be made into mats and other products to replace plastic. Preparing sedge threads includes harvesting, sorting by size and color, splitting, and finally drying them. Splitting is an important step because using equipment can increase process speed. The objective of this research is to design, build, test, and evaluate the performance of a sedge-splitting machine. The main feature of this machine is its two pairs of blades, 7 mm apart, arranged in a perpendicular manner. This allows splitting the sedges into four threads while simultaneously removing the core. Five sedge clums are simultaneously processed. The machine was tested at three roller speeds, 197, 205, and 214 rpm. Its speed is not constant but varies between the lowest and highest speeds. This process was compared to one employing manual labor. The quantity of sedge threads that the machine split varied with its speed. Therefore, the machine's overall production was estimated by averaging its output at these three speeds. It could process an average of 649.3 sedge culms/h, which is more than three times faster than the manual process, 195.4 culms/h. This research also studied the effect of culm moisture content on the machine's operating capacity. It was found that moisture content had no effect on the working rate of either the machine or the manual process. However, it did affect the machine's efficiency. Processing freshly cut culms enabled the highest efficiency, 90%. However, the manual process showed an average 98% efficiency when the culms had a moisture content between 84-90%.

**Keywords:** Splitting machine, Cyperus, Sedge, Double blade

## 1. Introduction

Production from natural materials or so-called eco-friendly materials will positively impact the environment, the quality of life of its people and make the world a better place [1]. Sedge is a natural material that can be used to make products to replace synthetic plastics in mats, baskets, bags, shoes, and placemats, among other products. It is a native plant that grows well in all regions of Thailand. Sedges are easy to plant, grow fast, and are highly disease and insect-resistant. Since it grows well in areas with standing water, it is easy to control weeds. It is truly an eco-friendly material [2, 3].

Products made from sedges are beautiful, smooth, shiny, have eye-catching colors, and are very durable. For example, Chanthaburi mats, a famous product of Chanthaburi, Thailand, are well-known domestically and internationally [4]. Currently, they are made from 100% natural materials. However, to produce beautiful mats or other products, the sedge threads must be small, smooth, and consistent for use in each of the exacting production steps [3]. The production process of materials made from sedges has the following steps: planting and harvesting, followed by preparing and dying sedge threads, weaving the product, and finally transforming it into other products [5, 6]. Every step is delicate and must be done meticulously to produce quality products. Considering only the sedge thread preparation step, this step starts with harvesting sedge culms (aerial portion of the plant), cutting the tips, and separating sedges of similar lengths (80, 100, 120 cm), and colors (light-medium-dark). Then they are cleaned by cutting off the tips, leaves, and branches that remain. Then, the sedges are split lengthwise and finally dried in the sun. Splitting the sedges must be completed quickly before they become dry and brittle [4]. Then, the sedges are woven into mats or other products [6]. Sedges must be fine and uniform in size so that the mats will be smooth, tight, beautiful, and of good quality [7]. Split or woven sedges that have been dried will cost approximately ten baht more per kilogram. It is therefore necessary to use skilled sedge weavers, who are becoming fewer. For example, one person who is over 70 years old, has worked as a sedge farmer for over 60 years. When the sedges are large enough, she harvests, sorts them by size, and splits them. When this material is sufficiently dry, she sells it to a mat weaving factory. Therefore, the critical step for this farmer is sedge splitting, which must be completed in a short time. So, some assistants are hired [8]. Local processors' capacity to produce well-finished products is affected due to a lack of necessary machinery and tools. Therefore, introducing and promoting modern processing machines and tools is crucial to making processors more competitive in the value chain [9]. Another solution is to apply technology to assist in sedge splitting [10], which is faster and less labor intensive. It also produces fine, smooth, and consistent sedge threads. At present, the equipment technology to assist in sedge splitting is not well developed. Kuljerm et al. [11] were the first researchers to apply technology to assist in sedge splitting. Their prototype is almost fully automatic, but it is not capable of removing the sedge cores while splitting. Later, Thonthan [12] developed an automatic sedge-peeling machine that could remove

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the sedge cores as well. However, this report provides no details of the machine operation or the impacts of sedge properties such as moisture content on the machine's operation.

*Sedge – Raw materials and applications*

Sedges are monocotyledonous plants that preferentially grow in low, moist areas with shallow water, similar to the conditions favorable to rice plants. Sedges occur naturally along the edges of ponds, swamps, rivers, and streams. When the demand for sedge as a raw material in the textile industry increased, its cultivation was developed [5]. There are many varieties of sedges. They are divided into two types: sedges and rushes, which differ in their cross-sectional shape and area [13, 14]. They are very similar in appearance. Sedges have edges, but rushes are round. In Thai, they are both called sedges. Both types can be used in industrial production, depending on preferences, climate, and familiarity in each area or community [15].

Sedges have underground and above-ground stems. The underground stem appears as a rhizome and grows parallel to and just below the soil surface. Therefore, sedges are important plants for soil and water conservation along the banks of water sources [14]. The above-ground stems (culms) are between 0.5 and 2.5 meters high, depending on the type and sedge variety. They have long, uniform stems with no nodes and are solid rather than hollow. Their leaves are located at the base with flowers and fruits at the top. Sedge stems are an ideal raw material to produce mats and mat products.

As the demand for sedges increased, the availability of natural sedges decreased, so it became necessary to cultivate them. Sedges can be propagated by seed, rhizome division, or tissue culture [14]. In Thailand, rhizome division is practiced in shallow water. Sedge cultivation is called sedge rice cultivation, as its cultivation techniques are identical to those of transplanted rice. Its cultivation requires a level, even field with dikes to control water. Planting begins in May or June, when the rainy season starts. Two plowing operations must be performed: plowing the fields once followed by a second plowing across the first plowed lines. Then, the fields are raked to remove weeds. Sedge seedlings, which consist of rhizomes and sedges that are about 30 cm high, are transplanted. The distance between rows and plants depends on the type of sedge and the size and height of the desired sedges [16].

The sedge harvesting period is uncertain. It depends on the type of sedge and the farmers' expertise. Sedges that are too young or too old will produce fibers that easily break. Products made from substandard sedges are not durable or beautiful. Farmers harvest sedges using a sickle or knife to cut the plant at its base. Then, the plants are cut to a specific length (called sedge salad) and tied into bundles. The sedge harvesting season is usually close to that of rice when the water in the fields dries up. Farmers use the time after the rice harvest to weave mats as a secondary occupation. This is done when the weather is cool and comfortable. In the rainy season, the sedge fibers will mold, while in the summer, they will break easily [7].

The quality of sedge products is impacted by every production step. There are five steps, planting and harvesting, sedge thread preparation, dyeing, weaving, and processing [5, 6]. Each step is complicated. Sedge planting requires good management of soil, water, and fertilizer, as well as disease and insect control. The water level in the field must be uniformly 10 cm deep. If it is too high, the sedge threads will easily break. When the water dries up, weeds will grow and the sedges will be stunted. Management of fertilizers, diseases, and insects requires specific knowledge [15, 17]. The sedge thread preparation process consists of harvesting, cleaning the sedge culms, splitting the sedges, and drying the sedge thread before dyeing, weaving, and processing, all of which are very complicated and require specialized knowledge.

*Double-Blade sedge Culm-Splitting machine*

After sorting the sedges by size and cleaning them, the next step is to split them into threads. One sedge culm can be split into 2 to 5 threads, depending on the needs of the mat weaver. Sometimes, they may not be split and the entire sedge culm can be used. However, if split, the sedge threads will be smaller. Smaller sedge threads produce finer, denser, and smoother mats [3]. However, this requires more time and effort. Usually, one sedge culm can be split into four threads, and the inner core must be discarded.

In splitting the sedges, the weavers use a short, sharp knife to pierce the culms, cutting from the base to the tip, starting about 20-30 cm from the base, depending on the length of the sedges. The base is cut until it breaks, and then the sedge core is removed. Splitting the sedges requires expertise and care. It is time intensive, especially when many mat factories and weavers need sedge thread. This is a critical period when the sedge thread demand is high. One weaver can split about 20 kg/day [11]. From a test by Srila [18], for 5- and 10-mm diameter sedges, weavers could split 409 and 419 sedge culm/h, respectively. This study found that the weavers could split only 190 to 204 sedge culm/h, which is much lower than reported by Srila [18].

From a survey of related research, there has been a slow development of simple devices or machines to split the sedge culms (Figure 1). Later, automatic machines were developed [18, 12] that employ the same principle. They use force to drive the sedge culm through a fixed blade. The driving force may be manual, semi-automatic, or fully automatic. Blade placement is also an important variable. Srila [18] used a wire blade. A single wire can cut a sedge culm into two threads. If two wires are placed perpendicularly to form a cross, four threads can be produced. Srila's device [18] is powered by manual labor. A laborer uses one hand to push the sedge culm through the blade slot and the other to pull the sedge thread away from the blades. Kuljerm et al. [11] placed blades in a perpendicular cross-pattern arrangement, similar to Srila's device [18]. However, their machine is semi-automatic. A laborer feeds the sedge culms through rollers that help drive them through the perpendicular blades that cut the culms into four threads. Another pair of rollers pulls the sedge threads out onto a receiving tray. In both cases, the sedge core remains attached to the sedge thread and must be removed manually before they can be used in the mat-weaving process. The machines of Srila [18] have a throughput of 677 and 643 sedge culm/h for 5- and 10-mm sedge culms respectively. The machine of Kuljerm et al. [11] can cut 40 kg of sedge culms/h.

Thonthan [12] designed, constructed, and tested an automatic sedge-splitting machine. In this research report, his machine could split sedge culms into four threads and also remove the cores. Unfortunately, the report did not give any details about the operation of the machine, but only the test results with 80 cm long sedge culms, 500 sedge culms at a time, with splitting rates of 1,029, 1,200, 960, 1,023, 1,143 sedge culms/h, an average of 1,071 sedge culms/h.

Most research related to post-harvest culm splitting was done in Thailand. However, research done in other countries involved culm harvesting machines [19], techniques for extracting threads from culms [20], and culm seed dryers [21].

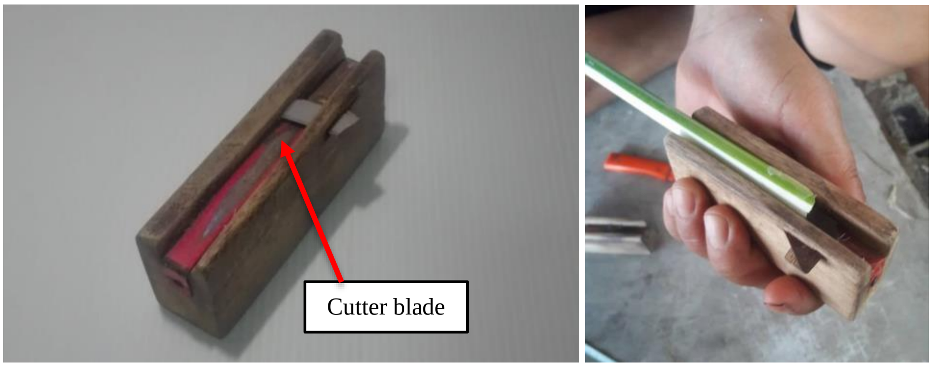



**Figure 1** A simple device for farmers to split sedges

*Research objectives*

The researchers realized the importance of the equipment for splitting sedge culms. Therefore, the objectives of this study were to design and develop a double-blade culm-splitting machine. High throughput and core removal are required while splitting the culms, as is production of consistent sedge threads. We also evaluated the machine's performance at different culm moisture levels.

## 2. Materials and methods

### *2.1 Physical properties of sedges*

*Cyperus* sedge culms (*Cyperus corymbosus* Rottb.) were harvested in Khon Kaen Province in the northeast of Thailand, and used as a raw material to assess this machine. The moisture content of the sedge culms was determined by drying small cut sedge pieces in a conventional batch-type dryer at 105 °C for 24 h. The performance testing section reports the moisture content of sedge culms prepared according to traditional methods.

The flow angle of sedges with the steel machine surface was determined. This angle was measured 20 times using separate 1-meter-long sedges (Figure 2). The average flow angle was 20.20±0.69°. The design of the sedge feeding tray used an angle of 20°.

The diameters of 300 1-m long sedges were measured at the base, middle, and end with Mitutoyo vernier calipers (Model 530-104, Japan) (Figure 3). The average diameter of the 90% range (5% outliers at the head and tail) was 8.97 mm (approximately 9 mm) and was used in the design (Table 1). The distance between each pair of blades was 7 mm to obtain a reed thickness of 1 mm according to the original practice of farmers. For the blade pipe set, the maximum diameter and ease of accessibility in the market are considered. Therefore, an 18-mm diameter PVC pipe was used.

**Table 1** The range of diameters of the sedge culms

| Frequency | Diameter Average (mm) |
|---|---|
| 0 - 45 | 6.96 |
| 46 - 855 | **8.97** |
| 856 - 900 | 12.36 |

**Figure 2** Testing the flow angle of sedges

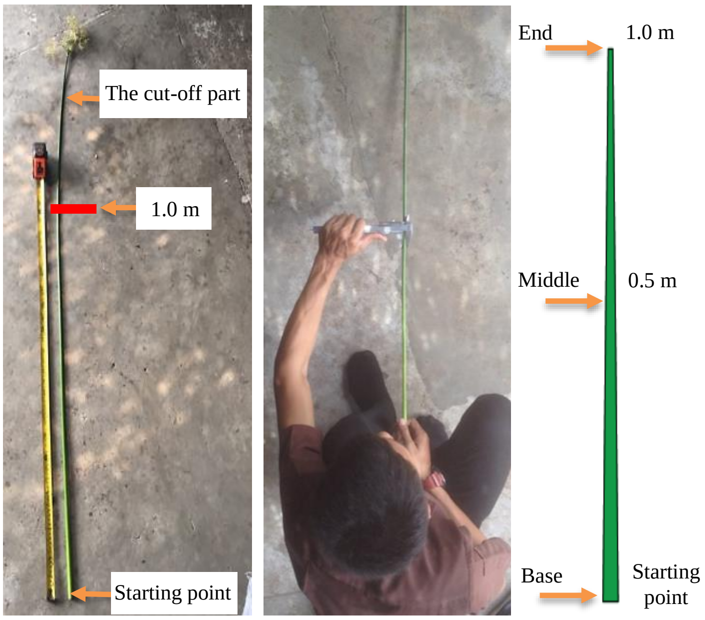
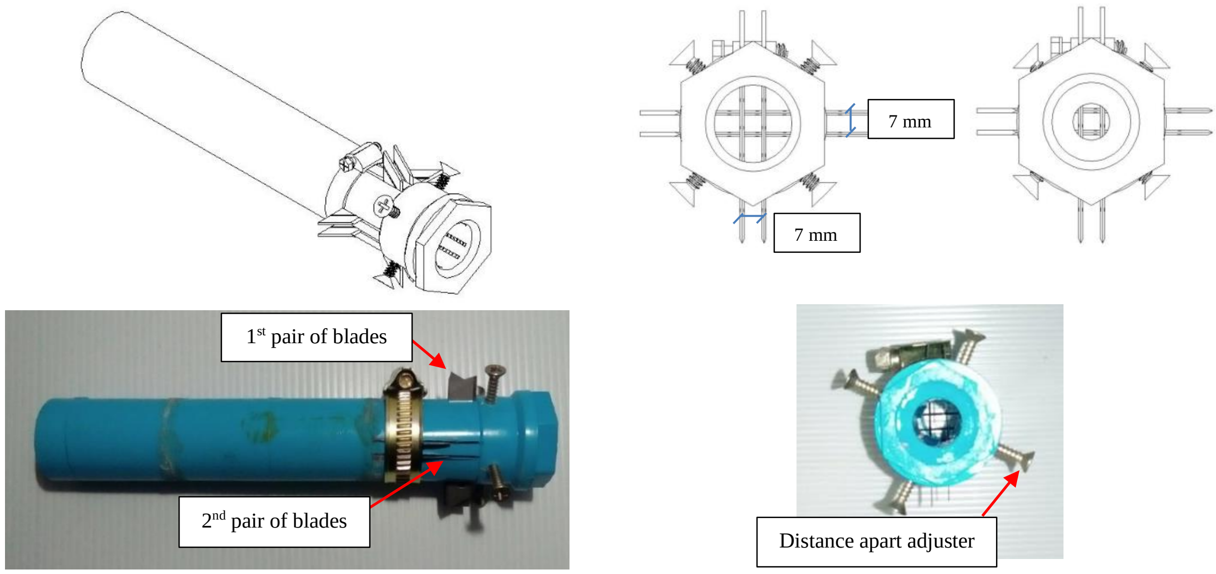



**Figure 3** Measurement of sedge diameters

*2.2 Double-Blade sedge Culm-Splitting machine description*

The sedge splitter in this study can simultaneously cut five sedge culms while removing their cores. The design uses two pairs of blades that are spaced 7 mm apart, perpendicular to each other. They are installed in an 18-mm diameter PVC pipe that is 0.15 m long. There are four bolts at an angle of approximately 45° to the blade direction used to adjust the distance apart so that the sedges pass through the center of the four blades (Figure 4). Two pairs of rollers are located at the entrance and exit of the blade pipe (Figure 5). The pair at the entrance drive the sedges into the pipe through the blades, which split the sedges into four pieces and peel away the core. The pair at the exit pulls the sedge threads and their core into a receiving tray. The rollers are 0.06 m in diameter and 0.49 m long fabricated from black steel pipe, wrapped with 3 mm of insulation, and secured with a layer of lacquer. The lower roller of the set at the outlet is connected to a 355.6-mm pulley, which is driven by a belt powered using a 1 hp motor operating at 1,400 rpm turning a 63.5-mm pulley. Simultaneously, the 355.6-mm pulley transmits power via a chain sprocket to the lower rollers at the entrance. The maximum speed of the roller set is 214 rpm, and the minimum speed that can drive the sedges through the blades is 197 rpm, a working range of 197 to 214 rpm. Two additional devices are the sedge feeding and receiving trays. Both trays are approximately the same size, 0.5 meters wide, 0.7 meters long, and 0.1 meters high. The sedge feeding tray is inclined 20° from horizontal and rests in a slot. All components are mounted on a frame made of 4 mm thick 40x40 mm angle iron (Figure 6).




(1) Blade placement position (2) Distance apart adjuster

**Figure 4** Blade placement position (1) and distance apart adjuster (2) of the blade assembly pipe

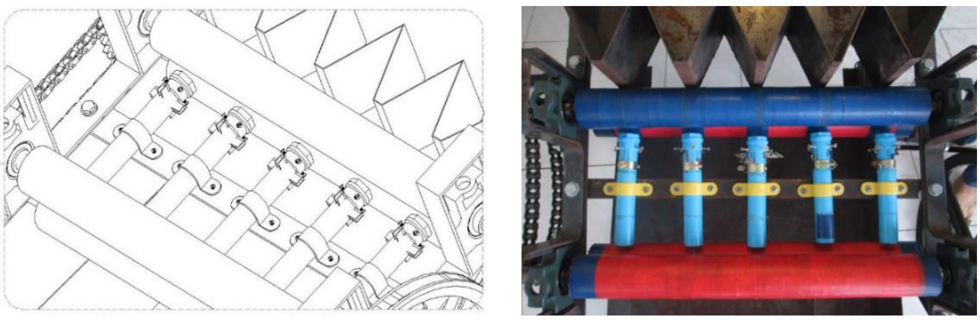


**Figure 5** Two pairs of rollers at the inlet and outlet of a pipe containing a blade assembly

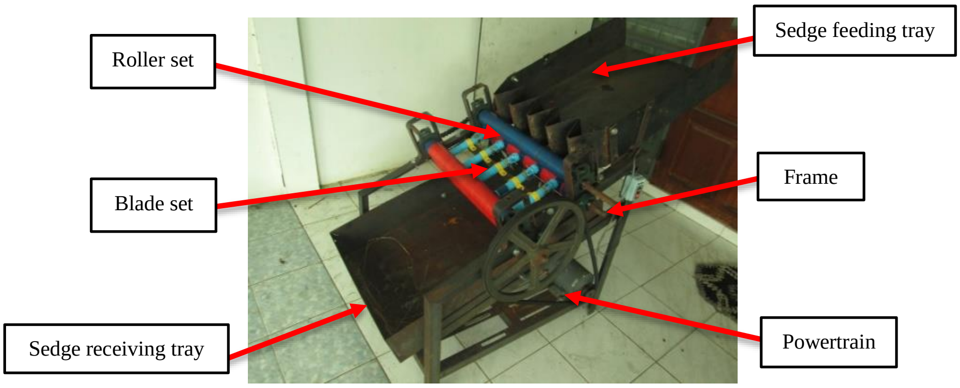



**Figure 6** Complete double-blade sedge slitting machine

A double-blade splitting machine for *Cyperus* sedge culms is a simple device. Its main components are knife blades that shear culms. The same shear principle is employed in a water hyacinth slitting and cutting machine [22], a two-way banana putty automatic slicer [23], a longitudinally aligned banana slicing machine [24], development of bamboo scrimber [25], and cross-sectional cutting of bamboo with a pair of knife blades for bamboo cube production [26]. The shearing principle of a double-blade splitting machine operation is shown in Figure 7.

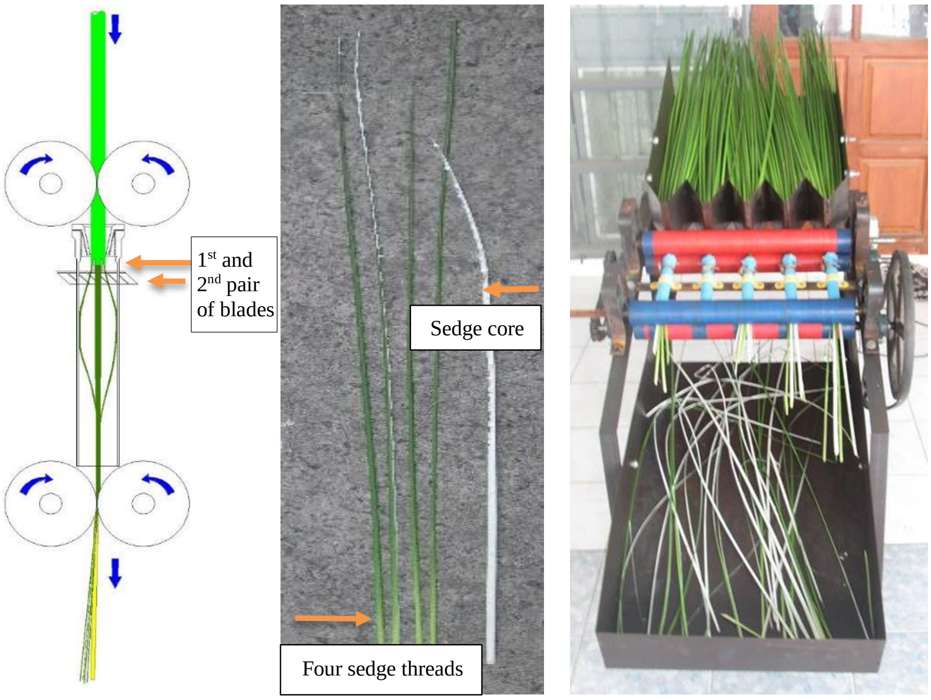



**Figure 7** Sedge cutting with double shearing blades

*2.3 Performance testing*

The researchers tested the machine by simulating actual conditions as closely as possible. The tests were conducted at Ban Nong Bua Thong, Khok Si Subdistrict, Mueang District, Khon Kaen Province, Thailand. This is the location of a large group of mat weavers/farmers who were able to develop and modify their mat products to meet OTOP (One Tambon One Product, where tambon means township or subdistrict) standards in 2015. The tests began by first training the farmers to familiarize them with the machine. Then, the farmers in that group tested the machine. The researchers collected and analyzed the data.

From pre-tests, the machine operates with rollers turning in the range of 197 to 214 rpm. Tests were conducted at three speeds, 197, 205, and 214 rpm. The test results from these three speeds were averaged to values that predict actual operational performance. In actual operation, the machine speed is not constant but varies between the lowest and highest values. Culm freshness is also a factor that affects efficiency of the splitting machine. This study found that newly cut culms lose water very quickly, and the rate of water loss decreases over time. On the day that the culms are cut, the average moisture content (wet basis) is approximately 90%. On the second day, it is approximately 86%, while on the third day, it is about 84% (Table 2). Since the moisture content of the sedge culms changes with time, we tested the sedge splitting machine at the above three average moisture contents using a traditional method. If the farmer did not finish splitting the sedges on the first day after cutting, the sedge bases were soaked in water to retard moisture loss.

**Table 2** Moisture content of sedge culms prepared according to traditional methods

| Method | $MC_{wb}$ (%) |
|---|---|
| 1. Normal moisture content of newly cut sedge culms | 90.05 |
| 2. Moisture content of sedge culms bases soaked in water for 1 day | 86.12 |
| 3. Moisture content of sedge culms bases soaked in water for 2 days | 84.32 |

The sequence of the sedge splitting tests was as follows. After starting the motor to check the machine's operation, the farmer distributed 20 round sedges, 100 cm long, onto the sedge feeding tray. The researchers started a timer. The farmer operated the machine in a manner to prevent the sedges from becoming stuck in the blade channel. When the sedges in the feeding tray were depleted, the farmer slowly added another 20 sedges onto the feeding tray. This continued until 100 sedges were processed. The researchers recorded the end time of each test set. Simultaneously, we had skilled farmers split the same number of sedges to compare the output capacity of the processes.

The data obtained from each set of tests includes the total sedge splitting time, the number of sedge culms fed into the system, and the number of sedge threads exiting the system (one sedge culm is split to produce four threads). Thus, the efficiency of the splitting process is the ratio of the number of sedge threads obtained to the number that can possibly be obtained from the culms fed into the system. This is expressed as a percentage, adapted from an equation by Guwo [27] who studied a ginger slicer.

$e = 100n/(4s)$ (1)

where e is the machine efficiency, n is the number of complete sedge threads split, and s is the number of sedge culms fed into the system. If the efficiency is expressed as a proportion, the 100 term in Equation (1) is omitted.

The operating capacity is four times the number of sedge culms passing through the system per unit time and can be written as [27].

$q = 4s/t$ (2)

where q is the operating capacity of the machine, and t is the time from when the first sedge culm enters the system until the last sedge thread exits the system.

The effective capacity of the machine refers to its rate of complete sedge thread production [28].

$p = eq$ (3)

where p is the effective capacity of the machine.

The quantity of damaged sedge threads to the total number of sedge threads obtained is given by Equation (4) [27].

$d = 100 – e$ (4)

where d is the percentage of damaged sedge threads.

## 3. Results and discussion

The operating capacity of the machine at three speeds compared with the farmers' splitting at three moisture levels is shown in Table 3 and Figure 8. When the speed increased, the working rate of the machine was naturally higher, averaging 550.6, 642.3, and 755.0 sedge culms/h at 197, 205, and 214 rpm, respectively. When these three values were averaged, 649.3 sedge culms/h were processed, compared with manual splitting, averaging 195.4 sedge culms/h. The machine has more than three times the output of the manual process.

**Table 3** Average operating capacity of the machine at different speeds compared with the manual process at various moisture contents

| Roller Speed (rpm) | Operating capacity of the machine (sedge culm/h) | | | |
|---|---|---|---|---|
| | $MC_{wb}$ (%) | | | Average |
| | 90 | 86 | 84 | |
| 197 | 546.8 | 539.8 | 565.2 | 550.6 |
| 205 | 654.3 | 648.3 | 624.2 | 642.3 |
| 214 | 763.4 | 765.1 | 736.5 | 755.0 |
| Average | 654.8$^a$ | 651.1$^a$ | 642.0$^a$ | **649.3** |
| Manual | 190.0$^a$ | 203.4$^a$ | 192.7$^a$ | **195.4** |

*Mean with different superscripts in the same row are significantly different by Duncan's Multiple Range Test ($p < 0.05$)*
where $MC_{wb}$ *(%)* is the moisture content (wet basis)

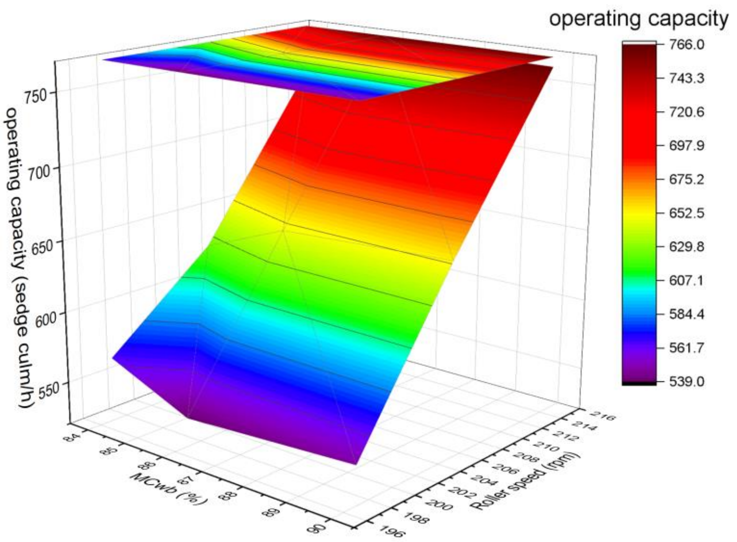



**Figure 8** Graphical representation of the average operating capacity of the machine at three moisture contents and different roller speeds

From Table 3, the moisture content did not have a significant effect on the processing rate of the machine or the manual process. At 197 rpm, the processing rate with fresh sedges was less than that of dry sedges, while at 205 rpm, the processing rate with fresh sedges was higher than that of dry sedges. Furthermore, the sedges were cut fastest by the machine at moderate moisture contents (Table 3). Sedge moisture content did not affect the processing rate of the machine or the manual process. However, sedge moisture content affected production losses, as shown in Table 4 and Figure 9.

Table 4 shows the average percentages of thread losses, 9.86, 16.11, and 16.97% at respective culm moisture contents (wet basis) of 90, 86, and 84%. When the culms are fresh, the machine can more efficiently split the sedges (lower losses). From Table 4, at a 90% moisture content (wet basis), the average thread loss is 9.86%, which is significantly lower than at 86 and 84% moisture contents. The 6th column of Table 4 shows the percentage of thread losses in the manual process. Moisture contents of 84-90% did not affect thread losses, which averaged 1.57-2.61%.

**Table 4** Average percentage of sedge threads losses during machine operation and conventional methods at three moisture contents

| $MC_{wb}$ (%) | Sedge thread losses (%) | | | | |
|---|---|---|---|---|---|
| | Roller speed (rpm) | | | | Manual |
| | 197 | 205 | 214 | Average | |
| 90 | 6.25 | 8.33 | 15.00 | 9.86$^a$ | 2.61$^a$ |
| 86 | 17.50 | 11.67 | 19.17 | 16.11$^b$ | 1.78$^a$ |
| 84 | 20.00 | 15.83 | 15.00 | 16.94$^b$ | 1.57$^a$ |

*Mean with different superscripts in the same column are significantly different by Duncan's Multiple Range Test ($p < 0.05$)*

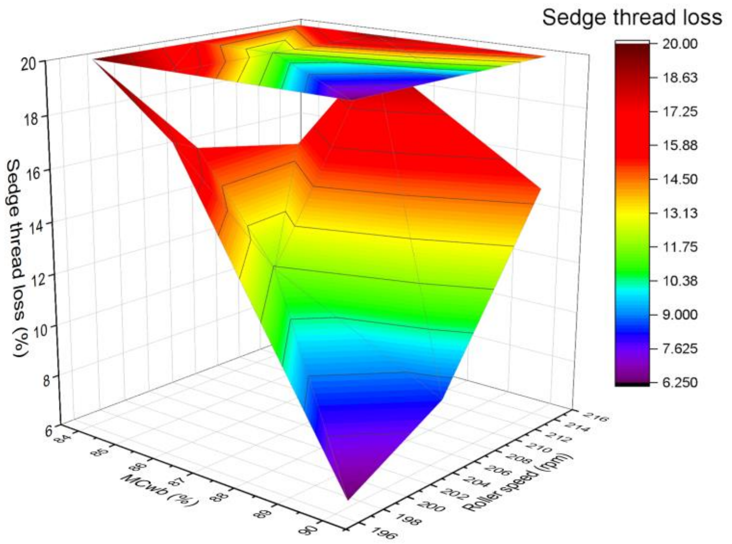



**Figure 9** Graphical representation of the average percentage of sedge losses of the machine operation at three moisture contents and different roller speeds

The percentage of sedge losses is related to machine efficiency in Equation (4). Machine and manual process efficiencies are shown in Table 5. Machine efficiency decreases with the culm moisture content. The efficiency of the manual process was not affected by moisture content. Efficiency (e) aids in calculating the working efficiency (p), which impacts the thread production of the system (Equation (3)). Table 5 shows that when the sedges are split while they are still fresh ($MC_{wb}$ 90%), the machine can process 590 complete sedge culms/h, while the manual process splits 185 sedge culms/h, a difference of 405 sedge culms/h. Working for eight hours per day, the machine can effectively process 4,722 culms, which requires about 5,239 sedge culms per day (where 1 culm can be split into 4 threads).

**Table 5** Comparison of the operating capacity of the machine with that of the manual process

| $MC_{wb}$ | Machine | | | | Manual | | | |
|---|---|---|---|---|---|---|---|---|
| (%) | $d$ (%) | $e$ (%) | $q$ ($h^{-1}$) | $p$ ($h^{-1}$) | $d$ (%) | $e$ (%) | $q$ ($h^{-1}$) | $p$ ($h^{-1}$) |
| 90 | 9.86 | 90 | 655 | 590 | 2.61 | 97 | 190 | 185 |
| 86 | 16.11 | 84 | 651 | 546 | 1.78 | 98 | 203 | 200 |
| 84 | 16.94 | 83 | 642 | 533 | 1.57 | 98 | 193 | 190 |
| Average | 14.31 | 86 | 649 | 557 | 1.99 | 98 | 195 | 192 |

$d$ = loss percentage, $e$ = efficiency, $q$ = operating capacity (sedge culms/h), $p$ = effective capacity (sedge culms/h)

The values shown in Table 5 are for the machine's average speed, not the optimum or maximum values as in other studies. The operating capacity of the machine in this study cannot be compared with other studies such as those of Srila [18], Kuljerm et al. [11], and Thonthan [12] because the test conditions are very different. For example, the working rate of the manual process in Srila's [18] study was 409 and 419 sedge culm/h. However, in this study, the manual process produced 190 to 203 sedge culm/h, which was less than half that of Srila's study.

This study is the first to examine the effect of culm moisture on their splitting rate and efficiency, both by a machine and a manual process. Culm moisture did not affect their splitting rate, by either the machine or in the manual process. However, moisture did affect machine efficiency. The machine was most efficient when the culms were very fresh (90% moisture). Therefore, the advantage of the machine is that it can work best with fresh culms, resulting in maximum efficiency and greater output. However, if a manual process was used to split the culms, there was a waiting time for the sedge culms to dry, which was time-consuming. However, the average efficiency of the machine (86%) was much lower than that of the manual process (98%) (Table 5). In this study of thread splitting compared with the study of Yangyuen and Laohavanich [29] (hard shell separation), macadamia nut (23-25 mm) mechanical shelling efficiency (87%) was much lower than that of the conventional methods (100%), similar to the current study.

## 4. Conclusions

The current work designed and constructed a double-blade sedge splitting machine that can simultaneously split five culms into four threads and remove the sedge cores. Three machine speeds, 197, 205, and 214 rpm along with three sedge moisture contents, 90, 86, and 84%, were evaluated. These results were compared with a manual sedge-splitting process. The machine's production rate varied with its speed, as expected. Sedge moisture content did not affect the production rates of the machine or the manual process, with respective average operation rates of 649.3 and 195.4 sedge culms/h. However, moisture contents between 84-90% (wet basis) affected the machine's operational efficiency but not that of the manual process. The highest operational efficiency of the sedge-splitting machine was 90% using fresh sedges. However, the manual process has an average efficiency of 98%, while the average efficiency of the machine is much lower, 86%. Further research is needed to improve machine efficiency.

## 5. Acknowledgements

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## 6. References

[1] Yagi K. Materials development for sustainable society: ecomaterials. The 39th annual conference of metallurgist of CIM; 2000 Aug 20-23; Ottawa, Canada. p. 3-13.
[2] Halada K, Yamamoto R. The current status of research and development on eco-materials around the world. MRS Bulletin. 2001;26(11):871-8.
[3] Benazir JAF, Manimekalai V, Ravichandran P, Suganthi R, Dinesh DC. Properties of fibres/culm strands from mat sedge - *Cyperus pangorei* Rottb. BioRes. 2010;5(2):951-67.
[4] Somboon L. The inherit of local wisdom of Chanthabun reed mat and community lifestyle: a case study of Thachabaeb Village in Bang Kacha Sub-district of Chanthaburi Province through knowledge management. Journal of Roi Kaensarn Academi. 2024:9(10):32-44. (In Thai)
[5] Nithisiriwaritkun W, Phonphuak S, Srisaphonphusitti T. Application of creative economy to reed mats products of Nongkoh Village, Ta Triang Tia District, Amphoe Landuan, Surin Province. Rajapark Journal. 2019;13(30):122-32. (In Thai)
[6] Kiddee U. Local wisdom knowledge management on reed mat of Banpang community, Mahasarakham Province [independent study report]. Khon Kaen: College of Local Administration, Khon Kaen University; 2011. (In Thai)
[7] Phason C, Chinsuwan W. Ban Phaeng reed industrial development Tambon Phaeng, Kosumphisai District, Mahasarakham Province. The National and International Conference on Business Management and Innovation; 2015 Sep 19-20; College of Graduate Study in Management, Khon Kaen University (MBA KKU), Thailand. p. 484-90. (In Thai)
[8] MGR Online. 72-year-old grandma fights her life, planted papyrus, sells them to a mat processing factory for a living [Internet]. 2014 [cited 2024 Apr 9]. Available from: https://mgronline.com/local/detail/9570000048410. (In Thai)
[9] Kidane B, Mekonnen Z, Getahun A, Anjulo A, Kassa H, Teshome U, et al. Highland bamboo value chains development to enhance local livelihoods in Southern Ethiopia. J Innov Entrep. 2024;13:50.
[10] Phoungmanee T, Charoensuk K, Jaingamdee P. Development of community product design based on participation of reed woven mat community enterprise group of Ban Huay Tard, Na Dok Kham Sub-district, Na Duang district, Loei province. DEC Journal. 2023;2(2):12-45. (In Thai)
[11] Kuljerm K, Nilklom C, Khanthong B, Thangen W, Moonhom W. Reed weave pilot [bachelor thesis]. Phetchabun: Production Technology Program, Phetchabun Rajabhat University; 2006. (In Thai)
[12] Thonthan C. Automatic system reed split machine. Yasothon: Yasothon Technical College, Office of Vocational Education Commission, Thailand; 2010. (In Thai)
[13] Haines RW, Lye KA. The sedges and rushes of East Africa. Nairobi: East African Natural History Society; 1983.
[14] Taman L. Using rushes and sedges in revegetation of wetland areas in the Southwest of Australia. Western Australia: Water and River commissions; 2001.
[15] Barua IC, Sarmah R, Barua KN. "Koth"- The Assam artisan mat from mash-weeds: an ethnobotanical approach. Research Inspiration. 2016;1(3):437-48.
[16] Pongrat A, Wanikorn N, Boonchareon P. Comparison of Thai sedge varieties in the low land part of Northeastern Thailand. Thailand: The National Research Council of Thailand; 2001. Report no. 04105861-0005.
[17] Jana K, Das SK, Puste AM. Production economics of mat-sedges (*Cyperus Tegetum* Roxb.) cultivation as influenced by water management practices for economic stability of resource-poor rural people of West Bengal, India. Int J Environ Agric Res. 2015;1(2):27-32.
[18] Srila M. Longitudinal cutting equipment for Papyrus reed. Prawarun Agricultural Journal. 2015;12(2):123-8. (In Thai)
[19] Zhu H, Wang D, He X, Shang S, Zhao Z, Wang H, et al. Study on plant crushing and soil throwing performance of bionic rotary blades in *Cyperus esculentus* harvesting. Machines 2022;10(7):562.
[20] Baye B, Tesfaye T, Teshome Z. Optimization of extraction techniques for processing and utilization of a new fiber from *Cyperus Dichrostachus A. Rich* plant. Polym Bull. 2024;81:2869-88.

[21] Xia X, Jin Y, Zhao H, Wang G, Huang D. Optimization and experiment of hot air drying process of *Cyperus esculentus* Seeds. Agriculture. 2023;13(3):617.
[22] Jaito K, Treeamnuk T, Treeamnuk K. Water hyacinth slitting and cutting machine. The 14th TSAE National Conference and the 6th TSAE International Conference 2013; 2013 Apr 1-4; Prachuap Khiri Khan, Thailand. p. 266-70. (In Thai)
[23] Inthata S, Srihabutra P, Thuanmunla J, Supad T, Inpalad P. Development of two-way putty banana slicer auto-machine. Journal of Science and Technology, Rajabhat Maha Sarakham University. 2022;5(2):103-115. (In Thai)
[24] Siriporn-akkharachai S, Siriporn-akkharachai T. Longitudinal and horizontal-aligned banana slicing machine. RMUTP Sci J. 2016;10(2):30-42. (In Thai)
[25] Huang Y, Ji Y, Yu W. Development of bamboo scrimber: a literature review. J Wood Sci. 2019;65:25.
[26] Ohuchi T, Nakahara M, Murase Y. Cross-sectional cutting of bamboo with a pair of shearing blades for bamboo cube production. J Wood Sci. 2006;52:274-8.
[27] Guwo AN. Development of a ginger splitting machine [thesis]. Nigeria: Ahmadu Bello University; 2008.
[28] Agbetoye LAS, Balogun A. Design and performance of a multi-crop slicing machine. Proceedings of the 5th CIGR Section VI International Symposium on Food Processing, Monitoring Technology in Bioprocess and Food Quality management; 2009 Aug 31 - Sep 2; Potsdam, Germany. p. 622-40.
[29] Yangyuen S, Laohavanich J. Development of a semi-automatic macadamia cracking machine. Eng Appl Sci Res. 2018;45(4): 256-61.