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Design, Fabrication, and Performance Evaluation of a Motorized Cocoon Deflossing Machine

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Abstract

A motorized cocoon deflossing machine was designed, fabricated, and evaluated at the College of Engineering and Applied Technology, Benguet State University to help speed up silk production. The motorized cocoon deflossing is comprised of body frame, deflossing assembly, hopper, discharging chute, and prime mover. On the performance of the cocoon deflossing machine, three speed treatments (85-97rpm, 98-113rpm, and 114-119rpm) were tested and analyzed. Results showed that the optimum deflossing is at 85-97 rpm, which has the highest deflossing efficiency (98.22%) among three treatments with a capacity of 1.11 kg/hr. Compared to the existing hand-driven cocoon deflosser used by the Philippine Fiber Industry Development Authority (PhilFIDA), the motorized cocoon deflossing machine has higher deflossing capacity and efficiency. The computed initial cost of the machine is PhP 15,212.63. Other assumptions such as the 60 days annual use and custom rate of PhP50.00/kg for the use of the machine were based on the harvesting of time and the quantity of harvested cocoons in PhilFIDA. The calculated payback period is two years with a return of investment of 40.18%.

Introduction

The art of silk production is called sericulture, which comprises cultivation of mulberry, silkworm rearing, and post cocoon activities leading to production of silk yarn (Food and Agriculture Organization [FAO], 2002). The silkworms produce an unreelable layer of silk over the cocoons called floss. Floss, a kind of silk fiber that comes out of saliva of the silkworm in the first stages of cocoon formation or spinning, is a silk waste that appears on the outer surface of the cocoon shell. Floss is separated from the cocoon by deflossing, done either manually or in deflossing machines to improve the cocoon quality (Lakshmi, 2016). Aside from clothing, silk woven fibers are also used for the construction of parachutes and bicycle tires. Silk fibers undergo a special manufacturing process and are used to construct prosthetic arteries. Due to silk's antibacterial properties, it is often used in the medical field for wounds and burns. Also, many silk fibers are woven into suitable backgrounds for pen and ink drawings and painting (Stanley, 2018).

The present global demand for silk is annually increasing by 5% (FAO, 2002). With the increase in population and increasing demand for fashionable clothing items due to fast changing fashion designs in developed countries, the demand for silk is bound to increase even more (FAO, 2002). According to Esteban (2008), in the Philippines, Benguet was chosen as the best site for sericulture since it possesses the right agro-climate that is favorable for the mulberry plants for successful rearing of silkworms. Philippine Fiber Industry Development Authority (PhilFIDA) reported that 70% of the 1,500 kilos of cocoons produced in Regions 1 and Cordillera in 2007 came from Benguet (Paroy, 2008).

Deflossing cocoon is a laborious and tiresome job. It involves workers who have to sit for long hours and manually remove the unreelable layer of cocoon. According to FAO (2002), floss must be removed for further processing (like reeling, silkworm egg production, and others).

Presently, the cocoon deflosser machine used in Benguet, specifically at Philippine Fiber Industry Development Authority (PhilFIDA) Regional Satellite Office in Wangal, La Trinidad is manually operated. Since it is manually operated, the drudgery of work is not minimized.

A motorized cocoon deflossing machine is needed to increase the deflossing capacity and efficiency and to limit human intervention. By using motorized cocoon deflosser, time for removing the unwanted floss on cocoons will be minimized and the drudgery of work will be reduced.

This study specifically designed, fabricated, and evaluated the performance of the machine in terms of its deflossing capacity and deflossing efficiency. The study also determined the optimum deflossing speed (in rotations per minute, rpm) of the machine and compared the deflossing capacity and deflossing efficiency of the fabricated deflossing machine with the existing manually hand-driven deflossing machine. Lastly, the study performed simple cost analysis on the use of the fabricated machine.

Materials and Methods

The motorized cocoon deflossing machine is comprised of body frame, deflossing assembly, hopper, discharging chute, and prime mover (Figure 1). The body frame is made up of 1 inch x 1 inch x 3/16 inch angle bar welded together where all the other parts of the machine were mounted by bolts and nuts and rivets. It supports the hopper, discharging chute and deflossing assembly, and serves as base for the prime mover. The deflossing assembly was made of cylinder, spiked rubber mat, and stainless round bar. The cylinder is made up of galvanized iron (GI) pipe with a diameter of 6 inches and with a length of 14 inches. The cylinder was covered with a spiked rubber mat to which the floss will be collected and be removed from the cocoon. One inch diameter shafting was also attached to the cylinder to cause the rotation. A 10 mm stainless iron rod was also mounted at the top the cylinder equipped with bearings for it to rotate and being pulled by springs to be attached steadily on the cylinder while rotating. The discharging chute and hopper was made using gauge #18 GI sheet bended and shaped to ease the passage of cocoons during operation. Lastly, 746 Watts (1 HP) motor was used as the prime mover.

Design Consideration

During the design conceptualization of the machine, there were criteria that were considered. First, the materials to be used must be locally available for easier and cheaper procurement. The machine must also be easy and safe to operate to avoid accidents during operation. Easy operation will also minimize the time of operation. Additionally, less number of operator will reduce the cost of operation of the machine.

Construction

The entire construction utilized locally available materials. The machine's main frame was first constructed (Figure 2). It is made up of 1 inch x 1 inch

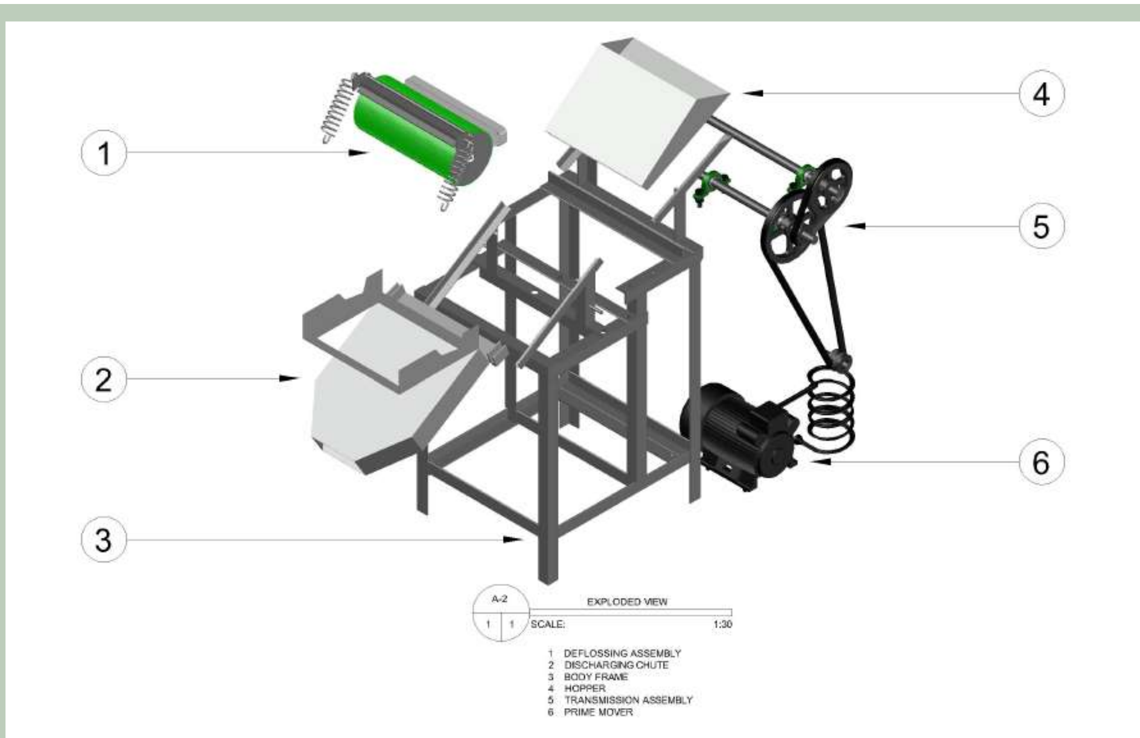

Figure 1. Design of the motorized cocoon deflossing machine

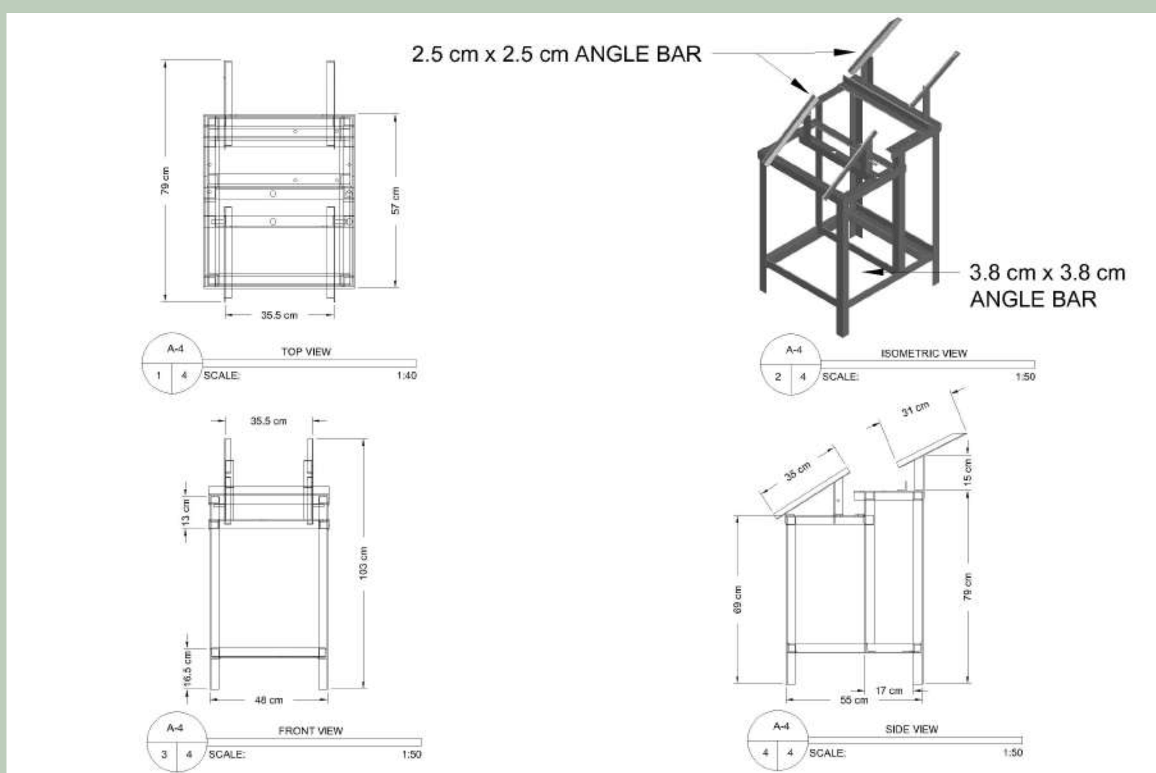

Figure 2. Main frame of the machine

x 3/16 inch angle bar welded together.

The deflossing assembly was made of cylinder, spiked rubber mat, and stainless round bar (Figure 3). It is made up of GI pipe with a diameter of six inches and with a length of 14 inches. Also, the cylinder was covered with a spiked rubber mat to which the floss will be collected and be removed from the cocoon. A 10 mm stainless iron rod was mounted at the top of the cylinder equipped with bearings for it to rotate and being pulled by springs to be attached steadily on the cylinder while rotating. One inch diameter shafting was also attached to the cylinder to cause its rotation.

The cocoons as input materials will be deflossed upon the rotational motion of the cylinder and stainless round bar. The power is transmitted to the cylinder through the pulleys connected on the circular shaft. The circular shaft is responsible for receiving the power from the motor. Further, the deflossing assembly is covered by a glass to ease the monitoring during deflossing time.

The hopper and the discharging chute, on the other hand, were made using gauge #18 GI flat sheet and were bended and shaped to ease the passage of cocoons during operation (Figure 4).

One HP or 746 Watts inductive type electric motor was used to provide power for the machine operation. To determine the deflossing speed to be used during the evaluation, the speed of the existing hand-driven cocoon deflosser in PhilFIDA in Wangal, La Trinidad, Benguet was determined. The speed is at 98-113 rotations per minute (rpm). Belts and pulleys (measuring 10 inches and 7 inches in diameter) were used to achieve this speed in the machine. Another pair of pulley measuring 10 inches and 6 inches in diameter was also used to achieve faster speed, which is ranging from 114-119 rpm as measured using tachometer. Slower speed was achieved by using pair of pulleys measuring 10 inches and 8 inches, which resulted to speed ranging from 85-97 rpm.

Principle of Operation

The operation begins when the cocoons as input materials will be fed into the hopper. The feeding is done by batch but it has to be continuous in operation. Each replication consists of 100 g of the input materials but the feeding is done in small quantity with 5 g continuously. Because the hopper is inclined,

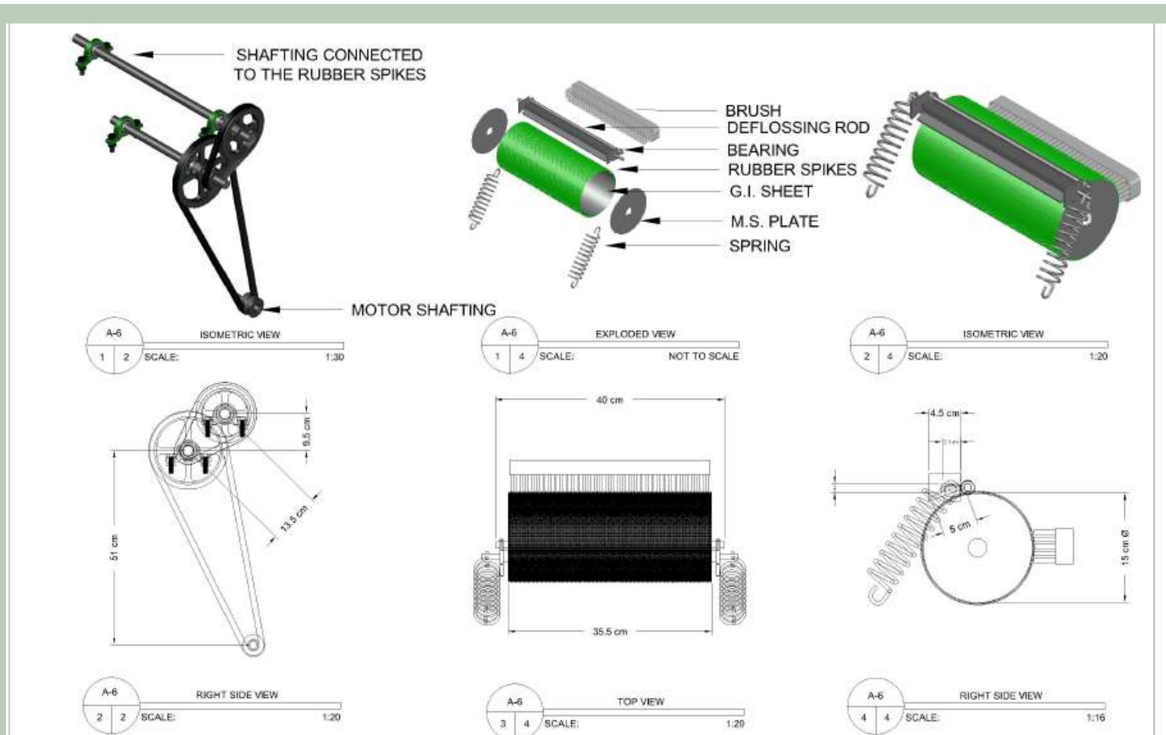

Figure 3. Deflossing assembly and power transmission assembly of the machine

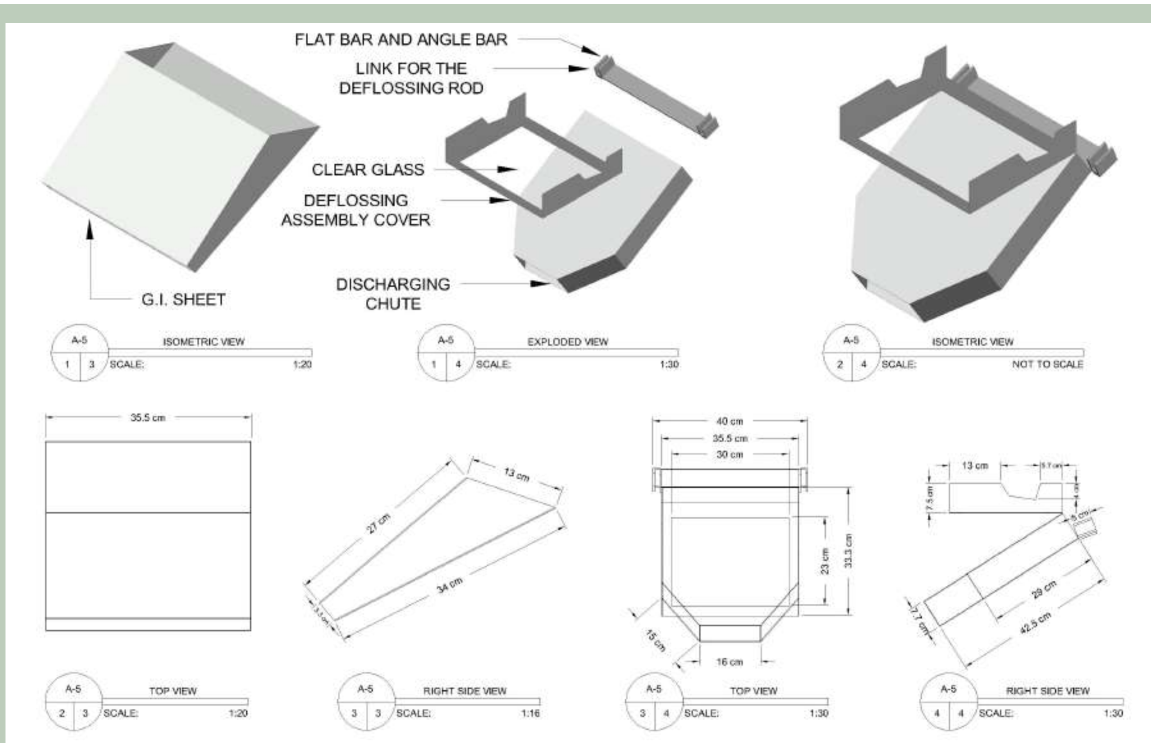

Figure 4. Hopper and discharging chute of the machine

the fed input materials will then be conveyed to the deflossing assembly.

The input materials will be deflossed upon the rotational motion of the cylinder and stainless round bar. The power is transmitted to the cylinder through the pulleys connected on the circular shaft. The circular shaft is responsible in receiving the power from the motor. The stainless round bar attached to the cylinder rotates in opposite direction with faster speed. It is being pulled by a spring so that it will be tightly attached to the cylinder. The floss is detached from the cocoon with the rotational motion of the cylinder. The floss is also attached to the spiked covering the cylinder and some are attached to the stainless round bar. The cocoons fall into the outlet tray after the floss is removed.

Performance Evaluation

In computing the deflossing capacity, the formula used is:

$$\text{Deflossing Capacity} = \frac{\text{Weight of deflossed cocoons (Kg)}}{\text{Operating time (hr)}}$$

Further, the formula used in computing the deflossing efficiency is:

$$\text{Deflossing Efficiency} = \frac{\text{Weight of deflossed cocoons (g)}}{\text{Weight of input cocoons} - \text{Weight of Floss (g)}} \times 100\%$$

Further, the data gathered include eight parameters of 11 evaluation. These include:

Weight of input materials (g). Cocoons that were used per replication were weighed before feeding them to the machine. One hundred (100) g of cocoon per replication was used and then fed by 5 g.

Operating time (min). It was the length of time recorded starting from the first feeding of the cocoon and ended when the last piece of cocoon fell to the outlet tray.

Weight of deflossed cocoons (g). The deflossed cocoons were collected from the outlet tray. These were the cocoons that were free of the thin outer loose layer. Based on the description of Mel L. Binwick (PhilFIDA), properly deflossed cocoons were free of the tangled fibers and the unreelable layers. By inspection, only the ends of filaments could be seen standing up from the cocoon.

Weight of the undeflossed cocoons (g). The undeflossed cocoons that were collected from the outlet tray were separated from the deflossed ones and weighed. Based on the description Binwick, these were the cocoons that contain tangled fibers and unreelable layers after being fed to the deflossing machine.

Weight of damaged cocoons (g). The damaged cocoons that were collected from the outlet tray were weighed. These are the cocoons that were flattened during operation.

Weight of floss retained in the output materials (g). Floss retained on the undeflossed cocoons from the output were manually removed and weighed.

Weight of floss collected from the machine (g). Floss that was collected by the (machine) deflossing cylinder, stainless rod and from the brush during the operation were removed and weighed.

Weight of floss (g). This was the total weight of floss from the cocoon, which is the weight of floss collected from the machine plus the weight of floss collected from the output materials

Statistical Analysis

Single factorial analysis in Completely Randomized Design (CRD with three replications) was used in this study. The factor was the speed replicated in three different revolutions per minute (rpm): 85-97 rpm; 98-113 rpm; and 114-119 rpm. Analysis of variance (ANOVA) was used to determine whether differences among treatment means are significantly different. The Duncan's Multiple Range Test (DMRT) was used to determine which among the means would be significantly different from each other. *T*-test analysis was also performed to compare the performance of the existing hand-driven machine and the motorized cocoon deflossing machine.

Economic Analysis

The cost of fabricating the machine is PhP 15,212.63. Some basic assumptions were considered to perform the simple financial analysis of the machine. The depreciation was determined using the straight line method with other assumptions such as: machine life of 10 years; interest on investment of 10%; tax and insurance of 3%; and repair and maintenance of 10%. The annual use of the machine was assumed to be 60 days and custom rate of Php 50.00/kg. These assumptions were based on the harvesting of time and the quantity of harvested cocoons in PhilFIDA in Wangal, La Trinidad, Benguet.

Results and Discussion

Machine Description

The motorized cocoon deflossing machine was designed to help increase the capacity and efficiency of deflossing cocoons (Figure 5). This can also help decrease the time consumption in manual deflossing operation. The machine comprises a frame, prime mover, hopper, deflossing assembly, and discharging chute.

The deflossing assembly is made of cylinder, spiked rubber mat, and stainless round bar. The cylinder is made up of GI pipe with a diameter of 6 inches and with a length of 14 inches. The cylinder is covered with a spiked rubber mat to which the floss will be collected and be removed from the cocoon. One-inch diameter shafting is also attached to the cylinder to

Figure 5. The motorized cocoon deflossing machine

cause its rotation. A 10 mm stainless iron rod is also mounted at the top of the cylinder equipped with bearings for it to rotate and being pulled by springs to be attached steadily on the cylinder while rotating.

The prime mover used is 746 watts (1HP) electric motor. It is used to rotate the deflossing cylinder through, shaft, belts, and pulley transmission system. The power is transmitted to the pulley by means of v-belts and is secured by shafting. The shafting is supported by two pillow block bearings that are firmly attached to the frame.

The determination of speeds that were tested was based on the speed used from the manually driven cocoon deflosser in PhilFIDA. The motorized cocoon deflosser was evaluated using a different speed. Higher speed (114-119 rpm) and slower speed (85-97 rpm) than the speed used in the hand-driven cocoon deflosser (98-113 rpm) were used. Each treatment level had three replications and was analyzed using Complete Randomized Design and Duncan's Multiple Range Test for the comparison of treatment means. The different speeds were obtained by changing the pulley sizes used for power transmission. Locally available deflossing material (spiked rubber mat) was also used in the machine.

Performace Evaluation

Weight of deflossed cocoon (g). The ANOVA shows that treatments belong to different treatments; thus, operating speed has a significant effect on the weight of deflossed cocoons. As shown on Table 1, as the deflossing speed decreases, the weight of deflossed cocoons increases. The highest weight of deflossed cocoon was observed at a speed of 85-97 rpm with 96.28 g out of 100 g cocoon input. Lowest weight of deflossed cocoons was recorded at 114-119 rpm. This is because as the speed increased, more cocoons directly fell from the deflossing assembly to the discharging chute without being deflossed. And as the deflossing speed decreased, lesser cocoons directly fell and more stayed at the deflossing assembly.

Weight of undeflossed cocoon (g). The operating speed has a significant effect on the weight of undeflossed cocoons (Table 2). The weight of undeflossed cocoons decreased as the speed of operation was reduced. As observed during the evaluation, as the speed increases, more cocoons

Table 1

Weight of Deflossed Cocoon, g

Treatment	Replication			Total	Mean
	1	2	3		
114 – 119 rpm	92.19	92.36	90.15	274.70	91.57[c]
98 – 113 rpm	93.11	94.27	93.85	281.22	93.74[b]
85 – 97 rpm	96.29	95.89	95.58	287.74	95.91[a]

Note: Means with the same letter are not significantly different at 5% level of significance

Table 2

Weight of Undeflossed Cocoon, g

Treatment	Replication			Total	Mean
	1	2	3		
114 – 119 rpm	5.63	5.08	6.01	16.72	5.57[a]
98 – 113 rpm	3.58	3.72	3.63	10.93	3.64[b]
85 – 97 rpm	2.05	2.13	2.28	6.46	2.15[c]

Note: Means with the same letter are not significantly different at 5% level of significance directly fall from the deflossing assembly to the discharging chute without being deflosssed. The faster rotation of the cylinder causes the cocoons to be directly thrown to the discharging chute whereas more cocoons are deflossed with the slower speed.

Deflossing time. Table 3 shows the significant difference among the treatments. Treatment with 85-97 rpm had the longest deflossing time since it was the slowest speed; therefore, it took more time for floss to be removed. Consequently, 114-119 rpm recorded the shortest deflossing time. It implies that the faster the speed being used, the lesser was the operation time of deflossing the cocoons.

Deflossing capacity. The machine capacity was calculated by taking the weight of properly deflossed cocoon and dividing it by the time of operation. Table 4 shows that capacity decreases as the speed decreases. The analysis shows that all treatment means are significantly different from each other. Treatment 85-97 rpm had the lowest capacity while 114-119 rpm had the highest capacity. It implies therefore that deflossing speed greatly affects the capacity of the machine. The comparison among replication shows that the highest capacity was recorded to be 1.55 kg/hr at 114-119 rpm. This is because the speed of operation reduced the time of operation. This is also the reason why the slowest speed (85-97 rpm) had the lowest capacity even if it had the highest weight of deflossed cocoons.

Deflossing efficiency. The highest deflossing efficiency of 98.22% was achieved when the machine was operated with 85-97 rpm (Table 5). Deflossing efficiency was directly proportional to the operating speed. It was observed during the evaluation that the weight of undeflossed cocoons increases as the speed was increases, which contributes to the inefficiency of the machine.

Machine performance. As shown in Table 6, the motorized cocoon deflosser had the highest efficiency at 85-97 rpm but the highest capacity was achieved at 114-119 rpm. According to the Philippine Fiber Development Agency (PhilFIDA), higher deflossing efficiency is preferred over having a high capacity since deflossed cocoons are needed for further processing (e.g., reeling, silkworm egg production, and others). Higher capacity with lower

Table 3

Deflossing Time per Replication, min

Treatment	Replication			Total	Mean
	1	2	3		
114 – 119 rpm	3.54	3.59	3.49	10.62	3.54[c]
98 – 113 rpm	4.34	4.5	4.47	13.31	4.44[b]
85 – 97 rpm	5.17	5.23	5.13	15.53	5.18[a]

Note: Means with the same letter are not significantly different at 5% level of significance

Table 4

Capacity of the Motorized Cocoon Deflosser at Different Speed, kg/hr

Treatment	Replication			Total	Mean
	1	2	3		
114 – 119 rpm	1.55	1.54	1.55	4.64	1.55[a]
98 – 113 rpm	1.30	1.26	1.26	3.81	1.27[b]
85 – 97 rpm	1.12	1.10	1.11	3.32	1.11[c]

Note: Means with the same letter are not significantly different at 5% level of significance

Table 5

Deflossing Efficiency of the Machine at Different Speed, %

Treatment	Replication			Total	Mean
	1	2	3		
114 – 119 rpm	93.35	94.57	92.37	280.30	93.43[c]
98 – 113 rpm	95.96	96.96	95.93	288.85	96.28[b]
85 – 97 rpm	98.81	98.58	97.27	294.66	98.22[a]

Note: Means with the same letter are not significantly different at 5% level of significance

Table 6

Performance of the Motorized Cocoon Deflosser in Terms of Deflossing Capacity and Deflossing Efficiency

Treatment	Deflossing Capacity (kg/hr)	Deflossing Efficiency (%)
114-119 rpm	1.55[a]	93.43[c]
98- 113 rpm	1.27[b]	96.28[b]
85-97 rpm	1.11[c]	98.22[a]

Note: Means with the same letter are not significantly different at 5% level of significance

deflossing efficiency would mean that there are more undeflossed cocoons, which will then be fed again into the machine and will add again to the operating time.

Comparison of Motorized Cocoon Deflosser to the Hand-driven Cocoon Deflosser

Table 7 shows the comparison of the hand-driven cocoon deflosser to the performance of the motorized cocoon deflosser. The operation of hand-driven cocoon deflosser involves the operator to manually rotate the handle while guiding the cocoons in the conveyor belt (Figure 6). The rotation of the cylinder and the conveyor belt will cause the floss to be detached from the cocoons. After being deflossed, the operator will let the cocoons to fall down on provided outlet tray/crates.

The operating speed of 85-97 rpm was used for the comparison since it had the highest efficiency. The machine is preferred to have a higher efficiency. The motorized cocoon deflosser had a better capacity of 1.11 kg/hr compared to the hand-driven, which can defloss 0.75 kg/hr of cocoon. In terms of efficiency, the motorized cocoon deflosser had an efficiency of 98.22%, which was higher than the efficiency of the hand-driven cocoon deflosser by 2.35%. *T*-test conducted shows that the two means in terms of capacity and efficiency were different at the 0.05

Table 7

Comparison of the Motorized Cocoon Deflosser to the Hand-driven Cocoon Deflosser

Parameters	Motorized Cocoon Deflosser(85-97RPM)	Hand-driven Cocoon Deflosser
Capacity, Kg/Hr	1.11	0.75
Efficiency, %	98.22	95.87

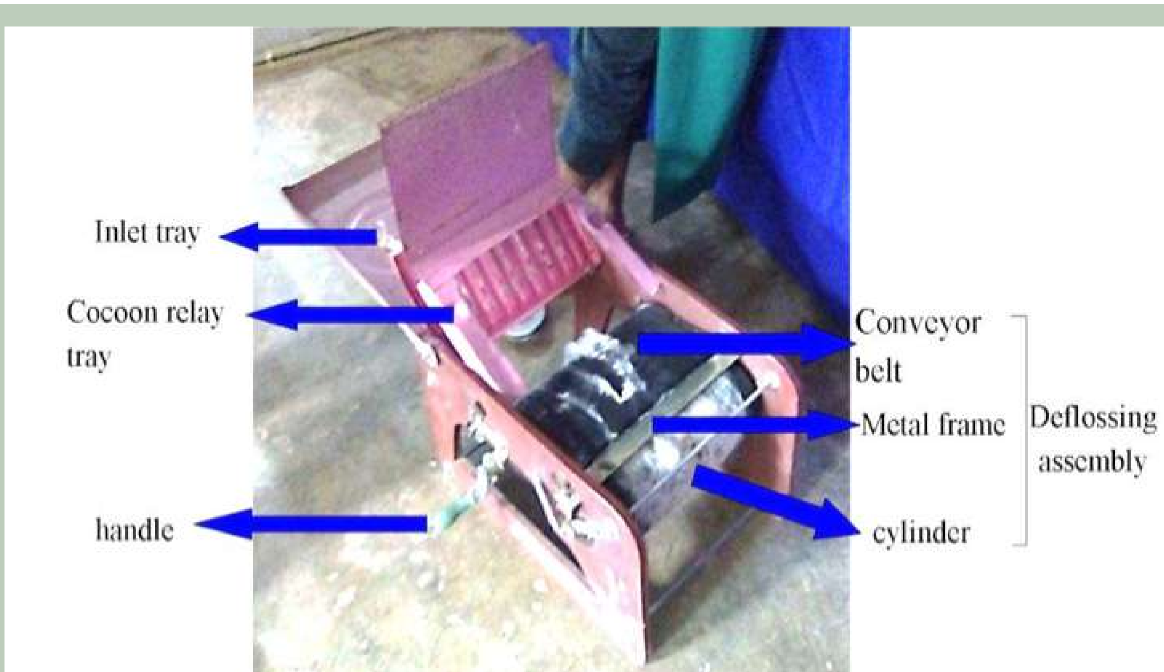

Figure 6. The hand-driven cocoon deflosser

significance level (Table 8 and Table 9). The motorized cocoon deflossing machine has a higher capacity and efficiency since human intervention is limited. Whereas, in the operation of the hand-driven cocoon deflosser, visual inspection of the operator is needed to determine if the cocoons are already deflossed and continuous operation is very tiresome.

Cost of Analysis of the Use of the machine

The initial cost for fabricating the machine is PhP 15,212.63 (Table 10). All the materials used were locally available. The annual use of the machine was assumed to be 60 days and of Php 50.00/kg custom rate. These assumptions were based on the harvesting

Table 8

Comparison of Motorized Cocoon Deflosser and Hand-driven Cocoon Deflosser in Terms of Capacity, kg/hr

	Mean	Variance	t-computed	t (5%)
Motorized cocoon deflossing machine	1.11	0.00043572	28.15*	4.303
Hand-driven cocoon deflosser	0.75	0.000164333		

Table 9

Comparison of Motorized Cocoon Deflosser and Hand-driven Cocoon Deflosser in Terms of Efficiency, %

	Mean	Variance	t-computed	t (5%)
Motorized cocoon deflossing machine	98.22	0.341744974	5.5875*	2.776
Hand-driven cocoon deflosser	95.87	0.566745944		

Table 10

Itemized Materials for the Construction of the Machine

Item	Materials/Description	Qty.	Unit	Unit Cost	Total Cost
Electric Motor	1 HP	1	pc	3200	3,200.00
Pillow Block	1 in (P205)	4	pcs	160	640.00
Pulley	2 in outside Ø , 1 in bore Ø, single groove	1	pc	200	200.00
Pulley	10 in outside Ø , 1 in bore Ø, single groove	1	pc	690	690.00
Pulley	6 in outside Ø , 1 in bore Ø, single groove	1	pc	390	390.00
Shafting	1 in Ø x 28 in	1	pc	300	300.00
V-Belt	A-26	1	pc	130	130.00
V-Belt	B-56	1	pc	300	300.00
Stainless Round Bar	10 mm x 16 ft	1	pc	500	500.00
Angle Bar	1 in x 1 in x 1/8 in	2	pcs	230	460.00
G.I. Sheet	Gauge #18	1	pc	960	960.00
G.I. Pipe	6 in Ø x 14 in	3	kg	30	90.00
Bolts and nuts		8	pcs	13	104.00
Bolts and nuts		4	pcs	8	32.00
Drill Bit	3/16 in	1	pc	65	65.00
Rivets	3/16 in x 3/4 cm	2	packs	5	10.00
Bearing		2	pcs	120	240.00
Sanding Disc		1	pc	85	85.00
Cutting Disc		5	pcs	40	200.00
Welding Rod	E6013	2	kgs	120	240.00
Rubber Mat		1	pc	155.75	155.75
Brush		2	pcs	45	90.00
Rugby		1	pc	63	63.00
Spring		2	pcs	40	80.00
Hinges		3	pcs	19	57.00
Primer Paint		1	can	110	110.00
Roller		4	pcs	150	600.00
Glass		1	pc	150	150.00
		SUB-TOTAL (PhP			10,141.75
	Labor Cost of the machine fabrication is 50 % of the material cost (PhP)				5,070.88
		GRAND TOTAL (PhP)			15,212.63

time and the quantity of harvested cocoons in PhilFIDA in Wangal, La Trinidad, Benguet (Table 11).

Some basic assumptions were considered to perform the simple financial analysis of the machine. The depreciation was determined using the straight line method. The machine was assumed to have 10-year life span with 10% interest on investment, 3 % tax and insurance, and 10% repair and maintenance. The assumptions on the custom rate of PhP 50.00/kg and annual use of 60 days were based on the harvesting time and the quantity of harvested cocoons at PhilFIDA Wangal, La Trinidad, Benguet (Table 11).

Table 11

Financial Analysis in the Use of the Machine

Basic Assumptions	
Initial cost	Php 15,212.63
Salvage value	10% of the initial cost
Estimated life, n	10 years
Interest	10%
Tax and Insurance	3%
Repair and Maintenance	10%
Total power	P 9.00/kW-hr
Capacity	1.11kg/hr
Annual use	60 days
Operation per day	8 hours
Number of operators	1 operator
Salary per day	P 275/ day
Custom rate	P 50/kg
1. Fixed Cost	
Depression Cost	P 1,369.14/yr
Interest on Investment	P 251.01/yr
Tax and Insurance	P 456.38/yr
Total Fixed Cost	P 2076.52/yr
2. Variable Cost	
Repair and Maintenance	P 0.32/hr
Labor Cost	P 34.375/hr
Power Cost	P 0.50/hr
Total Variable Cost	P 35.19/hr

Conclusions

Results showed significant difference among treatments in terms of deflossing capacity and deflossing efficiency. Moreover, optimum deflossing speed is determined to be at 85-97 rpm, which will result to 98.22% deflossing efficiency and 1.11 kg/hr deflossing capacity. The motorized cocoon deflossing machine performed better compared to the existing hand-driven cocoon deflosser in terms of deflossing capacity and deflossing efficiency. The computed initial cost of the machine was PhP 15, 212.63. With a 10 year machine life span, the annual revenue is PhP 26,588.53 with a total annual income of PhP 7,621.57 and a payback period of 2 years.

Recommendations

Based on the observations and conclusions, it is recommended to operate the machine at the optimum speed of 85-97 rpm. Modification of the deflossing assembly is also recommended to avoid the floss going to the round bar instead to the deflossing cylinder. This will also improve the machine's efficiency. Modification of the machine to optimize its parts will reduce its initial cost.

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