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Evaluation of Quick Covering Machine for Grain Drying Pavement

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Abstract

In sundrying the quality of the grains are greatly reduced when paddy grains were caught by the rain unsacked and unstored resulting to reduced profit. The objectives of this study were to design and fabricate a quick covering machine for grain drying pavement to test and evaluate the operating characteristics of the machine according to its deployment speed, recovery speed, deployment time, recovery time, power consumption, aesthetics of laminated sack and to conduct partial budget and cost curve analysis. The performance of the machine was determined using Complete Randomized Design (CRD) with three replicates under two operations. The three treatments were T_1-32 tooth, T_2-34 tooth and T_3-40 tooth auxiliary sprockets and the two operations were deployment and recovery. Results revealed that the machine was able to cover the grains in a 12.8 m x 22.5 m grain drying pavement at an average time of 17.13 s using a 40-tooth auxiliary sprocket with aesthetic value of 96%. It consumed 0.53 W-h for the deployment and recovery of the cover. The machine entailed an investment cost of $1,344.40 and an annual cost charge of $647.32. Moreover, the savings per year using the quick covering machine was $101.83.

Keywords: Quick, Covering Machine, Grain, Drying Pavement

1 Introduction

The Philippines is considered to be one of the top producing countries in terms of rice production yet the country imports rice (Philippine Center for Postharvest Development and Mechanization, 2011). This is due to the fact that growing population, climate change and poor postharvest handling were so much evident on the country. Among these three factors, there is only one thing human cannot control the climate change.

According to the latest survey done by World Bank (2012) Philippines experienced change in climate. It was revealed that frequent rainfall was experienced by the country compared to the past years. Therefore, the use of grain drying pavement for grain sun drying procedure is limited. The quality of the grains is greatly reduced when paddy grains were caught by the rain unsacked and unstored resulting to reduced profit (Bureau of Postharvest Research and Extension, 2010). The very quick change in weather is detrimental in drying paddy. Therefore, further technology development for drying pavement is one stage of paddy handling that requires immediate attention and positive action for agricultural engineers to address today.

Existing cover designs in the Philippines and from other countries were summarized in Table 1.

2 Materials and Methods

From the existing designs relevant features were selected and incorporated in the design prototype. The following features were fast deployment of cover, easy to operate, easy to construct, made of locally available materials, affordable, and covers the grain efficiently. The flowchart in Figure 3 showed the procedures for this study.

The quick covering machine for grain drying pavement has two major assemblies: frame and cover assembly (Figure 2) and power supply and transmission system assembly (Figure 3).

Table 1 Appropriate and inappropriate features of existing cover designs.

EXISTING COVER DESIGNS	APPROPRIATE FEATURES	INAPPROPRIATE FEATURES
Agricultural Film (China)	The film is durable against rainwater and it is easy to set-up	It cannot withstand sharp objects
Agricultural Storage Covers (India)	It provides protection from rain, water, dust and heat; it facilitates immediate rainwater discharge to the ground; made of locally available materials; and equipped with pulleys and cable wires	It is only applicable to cone shaped agricultural storage and the covering material is subjected to faster wear and tear
Grain Bunker Cover (Australia)	It is capable to cover conical shape stored grain and provided with rainwater drainage canal	Uncovering of grains during haulage is tedious and slow
Grain Pile Covers (Canada)	It facilitates faster deployment of cover and immediate water discharge	Allows possibility of rainwater to enter through the pipes
Grainpro-collapsible-dryer Case (Philippines)	Made of heavy duty black reinforced PVC; UV resistant; easily folded and transportable; prevent ingress of water; impermeable to water; handles for easy carrying; rodent safe storage; and easy to operate	Deployment of cover is very slow, requires high man power, and there is no proper rainwater discharge
Grain Storage (China)	It has durable covering material and facilitates immediate rainwater discharge	It is expensive, too high to construct and drizzle may enter the system through its open sides
Job Shops-tensioned Cover (England)	Rainwater and rodent birds or chicken cannot enter the system	It is expensive
MOR Compost Cover (California)	The design has good covering materials and is easy to operate	No discharge outlet for rainwater
MPC “tarp-on-first” Systems (USA)	It has a good water drainage system	Loading and unloading of grains is little bit laborious
Paddy Cover (Philippines)	Easy to operate, provided with housing and rainwater discharge	It cannot withstand wind gust, requires high man power and only applicable to a specially designed pavement
Polymax Grain Covers (New Zealand)	It is affordable, easy to construct and made of locally available materials	Allows possibility of rainwater entrance through open sides, there are no tensioners in both ends and it cannot withstand wind gust for a long time

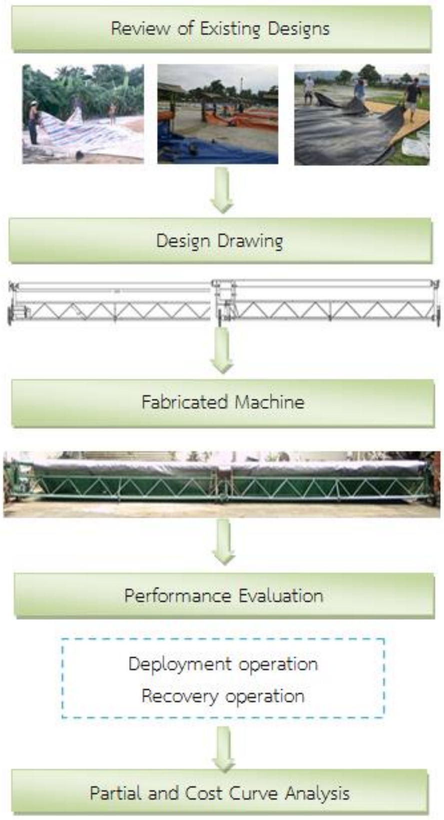

Figure 1 Process of the Study.

Figure 2 Frame and Cover Assembly.

Figure 3 Power Supply and Transmission System Assembly.

2.1 *Principle of Operation*

The quick covering machine was installed in a grain drying pavement to quickly deploy a cover to the grains being dried in the pavement in the event that rain occurred. The wheels of the device were placed on a rail so that it was guided as it moved in either forward or reverse direction. To operate the device the steps were as follows:

1) Switch on the toggle switch to provide power for the battery to the DC starter motor.

2) The DC starter motor drives the ring gear which in turn drives the wheel through a sprocket and chain transmission system.

3) As the device moves forward, the laminated sack (rolled in the spooler) with one end fix to the ground was deployed to cover the grains.

4) Upon deployment of the cover switch off the toggle switch to stop the forward movement.

5) When the rain stops and the grains were ready for sacking, switch on again the toggle switch for the recovery operation (Note: removed the chain connecting the front drive wheel and the auxiliary sprocket then use the other chain to connect the auxiliary sprocket to the spooler drive).

6) As the device moves backward the deployed laminated sack rolled back to its original position.

2.2 *Performance Evaluation of the Device*

The machine was powered by a 12 volts storage battery and thus the speed of the machine was speculated to vary during its deployment and recovery operation. Consequently, the speed of the machine affects the performance of the machine. Moreover, using the linear and angular speed formula 33 tooth sprocket was needed to acquire a speed of 4 km h^{-1} which is the average walking speed of man. Hence, to test the performance of the quick covering machine three treatments represented by 32-tooth, 34-tooth and 40-tooth were used at the auxiliary assembly.

2.3 *Statistical Analysis*

Analysis of variance (ANOVA) was used to analyze the experimental data under completely randomized design (CRD). Least Significant Difference was used for the comparison among means.

2.4 Experimental Set-up

The machine was tested using three different auxiliary sprockets size for two operations. The treatments were as follows:

Operation A - Deployment

Treatments:

A_1 ⟶ 32-tooth auxiliary sprocket

A_2 ⟶ 34-tooth auxiliary sprocket

A_3 ⟶ 40-tooth auxiliary sprocket

Operation B - Recovery

Treatments:

B_1 ⟶ 32-tooth auxiliary sprocket

B_2 ⟶ 34-tooth auxiliary sprocket

B_3 ⟶ 40-tooth auxiliary sprocket

2.5 Partial Budget and Cost Curve Analysis

To assess the economic importance of the machine simple cost analysis, partial budget analysis and cost curve analysis were done.

The assumptions presented in Table 2 were also taken into consideration. The result of annual cost charges was used in partial budget analysis.

Table 2 Assumptions for the computation of machine's annual cost charges.

Parameters	Assumption
Salvage value, SV	10% of IC
Useful life, n (yr)	
- Laminated sack	1
- Starter motor	5
- Battery	5
- Frames and others	10
Interest rate (%)	24
Repair and maintenance (%)	10
Taxes, insurance and shelter	3% of IC
Operating period (h/yr)	90
Drying period in wet season	30 days
Harvest (tons/ha)	7.2
Number of drying days/6 tons	2
Hours of operation (h/d)	3
Probability to rain/year*	80% of wet eason
Number of operator	1
Labor cost ($)	
- First dry**	4.5/ton
- Second dry**	4.2/ton
Battery charging cost ($)	0.99
Kilos/bag of paddy grain after drying	46

*based on the Philippine's weather condition for the past 3 years.

**based on prevailing cost of drying, 2011-2012.

3 Results and Discussion

The final modified quick covering machine was tested and evaluated. The results of performance evaluation were as follows:

3.1 Speed

The speed of the machine was tested using 32, 34 and 40 tooth auxiliary sprocket. The auxiliary sprocket was designed to drive 51-tooth front drive wheel sprocket.

Table 3 shows the three different deployment and recovery speed of the device as affected by auxiliary sprocket size. It shows that the 40-tooth auxiliary sprocket provided the fastest deployment and recovery speed compared to other auxiliary sprocket size. Also, 32-tooth auxiliary sprocket provided the slowest recovery speed among the treatments.

Analysis of variance revealed that the three auxiliary sprockets caused a significant difference on the deployment speed of the machine. On the other hand, it exhibited a highly significant difference on the recovery speed of the machine.

Results showed that the 40-tooth auxiliary sprocket allowed the machine to move faster than the walking speed of man which is 4 km h^{-1}. The larger the sprocket size the more effective is the machine since the aim of the machine was to cover grains before the rain drops. Also, to recover the device faster than 4 km h^{-1}, 40-tooth was to be used as an auxiliary sprocket. However, during recovery, it was not necessary for the device to move faster than the 4 km h^{-1} since the rain already stopped and grains were ready for sacking. Therefore, any of the auxiliary sprockets were acceptable as drive sprockets for the spooler drive during recovery.

Table 3 Speed (km h^{-1}).

AUXILIARY SPROCKET	MEAN*	
	DEPLOYMENT	RECOVERY
32-tooth	3.46^{a}	3.18^{a}
34-tooth	3.46^{a}	3.71^{b}
40-tooth	4.23^{b}	4.37^{c}

*Means with the same letters are not significantly different at 1% and 5% level using LSD.

3.2 Time

Table 4 shows that 40-tooth auxiliary sprocket revealed the shortest deployment time of 17.13 s. On the other hand, 32-tooth and 34-tooth auxiliary sprocket had the same deployment time. Also, it shows that the 40-tooth auxiliary sprocket allowed the device to move at the fastest time of 16.5 s compared to any other auxiliary sprocket size.

Table 4 Time (s).

AUXILIARY SPROCKET	MEAN*	
	DEPLOYMENT	RECOVERY
32-tooth	20.83^{a}	22.7^{a}
34-tooth	20.83^{a}	19.4^{b}
40-tooth	17.13^{b}	16.5^{c}

*Means with the same letters are not significantly different at 1% and 5% level using LSD.

Analysis of variance revealed that the three auxiliary sprockets caused a significant difference on the deployment time of the machine nonetheless, caused a highly significant difference on the recovery time of the machine.

Results showed that to acquire the fastest deployment time 40-tooth auxiliary sprocket should be used. If a larger sprocket size was used the lesser was the time of deployment. On the other hand, the smaller the sprocket size used the higher the time of deployment. Likewise, to recover the cover at the lowest possible time a 40-tooth auxiliary sprocket must be used. Moreover, it is not necessary for the device to move at the lowest possible time since the aim of the device was only to cover the grain. Recovery of the cover was only needed when sacking of grains were desired. Therefore, any auxiliary sprocket was acceptable in recovering the cover.

3.3 Power Consumption

Three 12 volts 70 AH batteries were used to test the machine. One treatment with three replicates used one battery. Likewise, the current and voltage used were monitored using an ammeter and a DC voltmeter, respectively.

Table 5 shows the power consumption of the device during deployment and recovery operation. It was revealed that power consumption of the device varied too much because of the experimental layout. The layout dictates the sequence of evaluating the performance of the different treatments in its power consumption. Since the power supply was a storage battery it discharged as it performed any of the operations.

Nevertheless, the 32-tooth auxiliary sprocket consumed the highest amount of electricity since it traveled in a longest time among the other auxiliary sprockets. On the other hand, the 40-tooth auxiliary sprocket consumed the least amount of electricity since it traveled in the shortest time among the other auxiliary sprockets.

It was also observed that for one operation (deployment and recovery) the device can consume a total of 0.53 W-h.

Table 5 Power consumption of the machine (W-h).

AUXILIARY SPROCKET	MEAN*	
	DEPLOYMENT	RECOVERY
32-tooth	0.25[a]	0.40[b]
34-tooth	0.30[a]	0.17[a]
40-tooth	0.22[a]	0.23[a]

*Means with the same letters are not significantly different at 5% and 1% level using LSD.

Analysis of variance revealed that the power consumption of the machine during deployment was not significantly different as influenced by sizes of auxiliary sprockets. Though, it revealed a significant difference in the power consumption of the device during the recovery operation as influenced by auxiliary sprocket size. The formula by Doughtie et al. (1965) as follows was used for the determination of the power consumption of the machine:

$$C = P \times t \tag{1}$$

where: C is consumption, (W-h), P is power or I (current) x E (volts), (W), t is time of operation, (h)

Results showed that the output power of the starter was dependent on the available voltage source and the ampere it drew. Since the starter motor was driving the same load on the deployment and recovery operation the power needed was also the same. However, since the voltage source was decreasing upon usage the output power may also decrease. Therefore, the minimal change in the voltage source caused a minimal change in power output and power consumption.

3.4 Aesthetics of Laminated Sack

Five randomly selected respondents rated the aesthetic value of the laminated sack during deployment and recovery operations. Table 6 shows that the aesthetic value of deploying the laminated sack was 96% good and the aesthetic value of recovering the laminated sack was 74.6% good.

It was also observed that the spooler support affected greatly the aesthetic value the laminated sack. The faster the passage of laminated sack in between the spooler and spooler support is the lesser the aesthetic value the laminated sack. Consequently, the faster the machine, the lesser the aesthetic value of the laminated sack. Therefore, the aesthetic value of the laminated sack was greatly affected by the forces acting on the spooler. Thus, the 32-tooth auxiliary sprocket is better to use if the aesthetic value the laminated sack is desired.

Table 6 Aesthetics of laminated sack.

AUXILIARY SPROCKET	MEAN	
	DEPLOYMENT	RECOVERY
32-tooth	4.8[a]	3.8[a]
34-tooth	4.8[a]	3.8[a]
40-tooth	4.8[a]	3.6[b]

*Means with the same letters are not significantly different at 1% and 5% level using LSD.

Analysis of variance revealed that the size of auxiliary sprocket showed no significant difference on the aesthetics of laminated sack during deployment but exhibited a highly significant difference on the aesthetics of laminated sack during recovery.

Results show that it is true that the laminated sack was in symmetry with the spooler which was the auxiliary sprocket is driving. The set-up caused the minimal change in the aesthetic value of the laminated sack among the treatments. The more symmetrical the set-up is the higher the aesthetic value. On the other hand, the lesser symmetrical the set-up was the lesser the aesthetic value of the laminated sack.

3.5 Partial Budget and Cost Curve Analysis

The machine total cost was $1,344.40. Table 7 shows a simple cost analysis for the annual cost charges of the machine. It shows that the machine operates for $647.32 annually. Annual cost charges only covers the wet season.

Table 7 Annual cost charges for quick covering machine.

COSTS	AMOUNT ($)
Fixed costs	
Depreciation	
Frames, wheels, spooler	107.54
Battery, 12 Volts, 3 smf, 70 AH	10.07
Starter motor, 12 Volts (2 units)	7.98
Laminated sack, 12 m x 23 m	44.35
Repair and Maintenance	
Frames, wheel, spooler	119.49
Battery, 12 Volts	5.59
Starter motor, 12 Volts (2 units)	4.43
Laminated sack, 12 m x 23 m	4.93
Interest on Investment	177.46
Taxes, Insurance (3% IC)	40.33
Total fixed costs	522.16
Variable costs	
Battery charge cost	0.99
Labor cost	
Wet season (7.2 tons), 4 days of drying	
First dry ($4.5 ton^{-1}), 2 days of drying	65.04
Second dry ($4.2 ton^{-1}), 2 days of drying	59.13
Total variable costs	125.15
TOTAL COST	647.32

Furthermore, by partial budget analysis as shown in Table 8, it was revealed that if a one hectare rice land owner uses a quick covering machine during drying operation, he can save $101.83 year^{-1} given that the rewetted palay can be sold for $0.27 kg^{-1}.

Moreover, Figure 4 shows that the operating cost of the machine can be compensated for saving 1.53 tons per year. Therefore, a savings of 5.3 tons can offset the cost of the machine.

Table 8 Partial budget analysis for quick covering machine (rewetted palay sold by $0.27 kg^{-1}).

Income Reducing, Losses ($)		Income Increasing, Gains ($)	
Added Costs		Added Returns	
Fixed cost	522.16	Sales	530.38
Variable cost	0.99		
Reduced Returns		Reduced Costs	
None		Labor	94.60
Sub-total A	523.15	Sub-total B	624.98
Net Change in Income (B-A)	101.83		

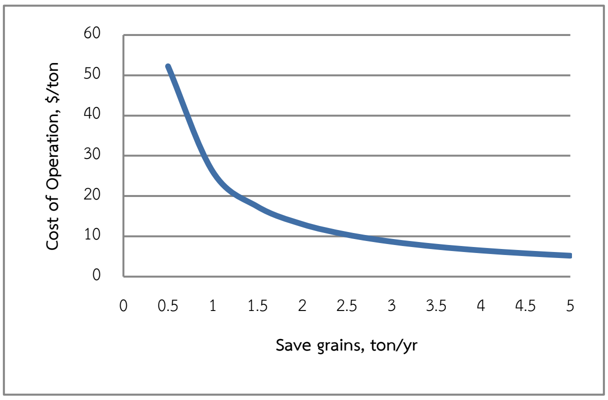

Figure 4 Cost curve of using quick covering machine.

4 Conclusion

The quick covering machine for grain drying pavement was designed to minimize the problem in the rewetting of grains during sun drying. It was made up of locally available materials and fabricated with simple intermediate technology. The machine was able to cover the grains in a 12.8 m x 22.5 m grain drying pavement at an average time of 17.13 s. The machine consumed 0.53 W-h for the deployment and recovery of the cover.

During the performance evaluation, it came out that the 40-tooth auxiliary sprocket revealed a deployment speed of 4.23 km h^{-1} and recovery speed of 4.37 km h^{-1}. On the other hand the 32-tooth revealed a deployment speed of 3.46 km h^{-1} and recovery speed of 3.18 km h^{-1}. Nonetheless, 34-tooth auxiliary sprocket revealed a deployment speed of 3.46 km h^{-1} and recovery speed of 3.71 km h^{-1}. Moreover, the difference between the aesthetic values of the laminated sack as affected by auxiliary sprocket size was minimal. However, it was observed that the aesthetic value of the laminated sack was better during deployment than during the recovery.

The machine entailed an investment cost $1,344.40 and an annual cost charge of $647.32. Moreover, the savings per year using the quick covering machine was $101.83 and the break-even point of using the quick covering machine was 1.53 tons. Hence, the machine was recommended for rice millers, traders and medium to large scale farmers.

5 Acknowledgement

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