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Evaluation of a Helix Type Potato Grader

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ABSTRACT

Uniformly graded tubers command a premium price in the market over the ungraded one. Likewise, in the potato processing industry graded tubers promote ease of handling resulting to an increased efficiency of the processing line.

This study presents the evaluation of the performance of a fabricated potato grader that uses a rotating helix of increasing gaps as a medium of gradation. Response variables are the grading system efficiency in percent, capacity in kg/hr, percentage of damaged tubers and power consumption. These were evaluated on the speed of the grading unit in RPM and inclination of the grading unit in degrees.

Results of the evaluation showed that the grader had its optimum performance when operated at 15 RPM and inclination of 10 degrees giving a system efficiency of 92.56%, capacity of 441.58 kg/hr, less damaged tubers of 1.83% and a low power consumption of 22.6 W-hr. The cost of the grader is P31, 000.00 with a break-even quantity of 23 tons of tubers/year. The capacity of the device can be increased by considering a larger diameter of the grading unit.

Key words: Laborious, manual grading, potato grader, premium price

INTRODUCTION

In the Philippine setting, particularly in the cordillera, farmers in the potato farming business remain in the traditional method of classifying potato tubers into homogenous size. Most often they bring their bulk of harvested potato tubers in the market and they perform manual grading. This operation consumes significant amount of time resulting to a delay on the disposal of harvest not only the potato but other products in the market. In the case where the market area is limited, incoming harvest needs to queue over a period of time to wait for some market space. Agricultural produce when not sold early will decrease in quality. The chance of the farmer to sell their product at a higher price would be lost in addition to some lost in their product due to degradation. Grading of potato tubers by hand is less efficient and inconsistent as human perception varies from one another. It is also time consuming causing muscle fatigue and stress to the farmers. On the other hand as reported by Dattatraya L et al (2013) grading is considered a very important operation in the marketing line as it can fetch higher price to the farmers.

Previously a similar study conducted by the author (2015) which was published in the IRJIEST 2015. The grading process of the previous study includes the use of a separate unit of conveyor. Potato tubers were first loaded into the hopper of the conveyor and then deliver it to the hopper of the grader. The system was found to have an acceptable performance. However, removing the conveyor and directly loading the tubers into the hopper of the grader could possibly reduce the time of operation and abrasion on the skin of the tubers; hence this study was conducted to evaluate the grader without the conveyor.

Meanwhile, potato tubers were reported by Shaym et al (1982) and Butler GP et al 2005 to be best graded by mass. However grading the tubers by mass is not customary and impractical as revealed from the findings of Fahardi et al (2004). Some studies were also conducted to find a substitute way of grading potato tubers based on mass like the study of Tabatabaeefar (2002) where he found that there was a strong relation between minor diameter and mass. As to the size of the tubers, Mahirang et al 2009 provided a basis on the classification of potato tubers as small, medium and large with minor diameters of 3.0-3.9 cm, 4.0-7.4 cm and 7.5 cm in above respectively.

This study was then conducted to evaluate the performance of the spiral type potato grader in terms of grading system efficiency, capacity, percentage of tubers damaged by the grader and power consumption; establish the optimum operating machine parameters such as speed of the grading unit (RPM) and inclination of the grading unit (degrees); and perform simple cost analysis of the device in terms of break even cost.

MATERIALS AND METHODS

Potato grader: Shown in Figure 1 is the conceptual design of the potato grader that was initially fabricated. The unit comprises of a hopper, grading unit, prime mover, catchment tray mounted on a frame. The hopper serves as guide for the potato tubers into the grading unit. The grading unit is a spiral type with increasing gap starting from the inlet. The spiral assembly has three regions: the region for small, medium and large-sized tubers. The first region has gaps that allow only small tubers to pass. The gap of the spiral for this region ranges from 3.0 cm to 3.9 cm. The second region has gaps of 4.0 cm up to 7.4 cm allowing medium sized tubers to pass. The third is the region for the large tubers with gaps greater than 7.5 cm. Below the spiral is a catchment tray for the graded tubers. The tray has three divisions to separate the graded tubers from the regions of the spiral.

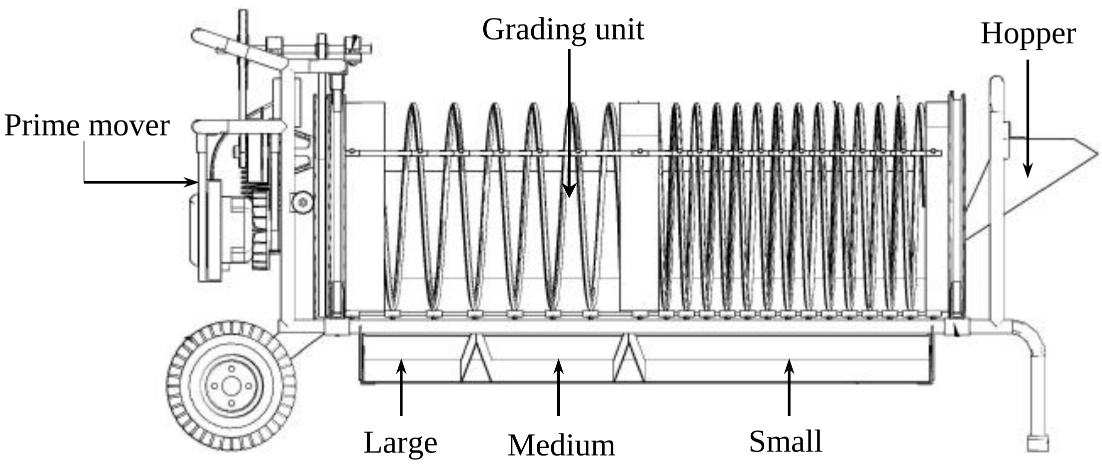

Figure 1. Conceptual design of the potato grader

Operation: The principle of operation of the device begins with the rotating motion of the grading unit through the prime mover. Tubers with minor diameters pass through the gaps during rotation to the collection tray provided below the grading unit.

Machine parameters: Two machine parameters were used during the evaluation. These were the speed of the grading unit (10, 15 and 20 RPM) and the inclination of the grading unit (5, 10 and 15 degrees). The influence of these machine parameters to the performance of the machine during the evaluation was observed. Machine performance, response variables, was indicated by the grading system efficiency (GSE) in percent, capacity (C) in kg/min, percent damage tubers and power consumption in W-hr.

The grading system efficiency was determined by taking the products of the efficiency of small, medium and large regions as shown in Eq. 1. Where eff_s is the efficiency, in decimal, of the small region of the grader to classify the small tubers, eff_M is the efficiency of the medium region and eff_L is the efficiency of the large region.

$$GSE = (eff_S \; x \; eff_M \; x \; eff_L) x \; 100; \; \% \qquad \text{Eq. 1}$$

The capacity of the grader was determined by considering the time it takes to grade the given quantity of tubers. In this study 20 kg of tubers were used. The capacity is expressed in kg/hr as shown in Eq. 2, where t is time in seconds.

$$C = \frac{1200}{t}; kg/hr \qquad \text{Eq. 2}$$

The power consumption was taken by simply taking ng products of the rated size of the prime mover of the grader and the time of operation. In this study ¼ hp motor was used. Power consumption is related by Eq. 3 where t is seconds.

$$P = \; 0.05t, W - hr \qquad \text{Eq. 3}$$

Damage: Damage was accounted as those tubers with abrasion after the grading operation. The percentage of damage tubers were taken by considering the total number of tubers with abrasion after the operation against the total number of tubers prior to the operation. Abrasion was visually inspected and those tubers with abrasion of 5% higher than the surface area were considered damaged as shown in Eq. 4.

$$Damaged\ tubers, \% = \frac{Total\ number\ of\ tubers\ with\ abrasion}{Total\ number\ of\ tubers\ in\ the\ sample} \; x \; 100 \qquad \text{Eq. 4}$$

Samples: A quantity of 540 kg of Potato tubers were procured from the fresh delivery of farmers at the La Trinidad Vegetable Trading post in November 7, 2015. Tubers with initial damages such as scratches, abrasion, decay and greening were not considered in the sample. Thus, there was no initial damage during the testing of the device. The samples were divided into 27 groups with 27 kg each containing small, medium and large. On the average, each group had 48% small, 32% medium and 20% large-sized tubers. Each tuber was manually measured with Vernier caliper to determine the size and was given a label to easily distinguish after grading.

Test run: A test runs of 27 were used in the study with 9 treatment combination and 3 replications. Each replication used 20 kg of potato tubers as initially prepared.

Evaluation procedures: As initially prepared, each 20kg of potato tubers were loaded into the hopper while the grading unit is rotating. After the grading operation, tubers that dropped on the appropriate region were counted and recorded. This is to determine the grading efficiency of each region as shown in Eq. 4, 5 and 6. The time, in seconds, it took to grade the samples were also recorded.

$$eff_S = \frac{Number\ of\ correctly\ graded\ small\ tubers}{Total\ number\ of\ small\ tubers\ in\ the\ sample} \quad \text{Eq.5}$$

$$eff_M = \frac{Number\ of\ correctly\ graded\ medium\ tubers}{Total\ number\ of\ medium\ tubers\ in\ the\ sample} \quad \text{Eq. 6}$$

$$eff_L = \frac{Number\ of\ correctly\ graded\ large\ tubers}{Total\ number\ of\ large\ tubers\ in\ the\ sample} \quad \text{Eq. 7}$$

Economics of the potato grader: Break-even point of the device was considered in this study which is expressed in terms of the amount of tubers needed to grade per year. The analysis included the actual cost of the device, custom rate, annual cost, depreciation, insurance and tax and repair and maintenance or the fixed and variable cost. Break even cost of the device is given by Eq. 8 where CR is the custom rate, AFC is the annual fixed cost and VC is the variable cost.

$$BEP = \frac{AFC}{CR\text{-}VC} \quad (8)$$

RESULTS AND DISCUSSION

A. Influence of Speed

Data in Table 1 shows the performance of the grader at different RPM. It shows that the grader had the highest GSE when operated at 15 RPM. Extremely fast RPM of the grading unit were observed to cause the tubers a random movement. This mechanical reaction caused some tubers to jump over several gaps to the extent that small-sized tubers even jump to the region of the spiral for medium-sized classification. This unwanted motion of tubers during extreme rotation significantly affected the grading system sufficiency of the device. On the other hand, lower RPM (10 RPM), tubers were observed to accumulate in the grading unit due to slow speed causing multi-layering, hence some tubers were also observed to pass over several gaps. In some instances small tubers were layered to the larger one and carried either into the medium region or even to the large region.

Table 1. Performance of the grader as influenced by the speed of the grading unit

Machine parameters	Speed (RPM)		
	10	15	20
Grading System Efficiency (GSE), %	87.1^{a}	88.18^{b}	72.03^{c}
Capacity, kg/hr	813.4^{a}	884.2^{b}	893.8^{b}
Damaged Tubers, %	2.101^{a}	1.797^{b}	1.723^{c}
Power Consumption	12.265	11.30^{b}	11.16^{b}

Means having the same letter along row are not significant

The capacity of the grader at 15 and 20 RPM was significantly higher than at 10 RPM. High speed (20 RPM) induces more velocity to the tubers causing them to travel along the unit at a faster rate. However, there velocity resulted to insufficient resident time for the tubers to interact with the spiral. Conversely, lowest speed (10 RPM) resulted to slow material flow through the grading unit resulting to longer time of operation that caused lower capacity. The slow movement of tubers along the gaps of the spiral caused accumulation of tubers which formed multi-layering. In this situation, some tubers were carried over by the layer to the region of next classification without gradually passing the gaps of the spiral. This explains why efficiency was lower at extremely high and low RPM.

Power consumption was lowest at 20 RPM. The grader operated at a faster rate causing shorter time of operation. Lowest speed (10 RPM) resulted to more power consumption. Tubers stayed at a longer time in the unit causing more power inputs.

Damaged tubers was minimal at 15 and 20 RPM while highest damaged was observed at 10 RPM as illustrated by the graphs in Figure 2. Slow speed (10 RPM) caused accumulation of tubers in the grading unit that induced greater impacts as a result of their weight. The combined effect of the speed of the grading unit and the heavy weight of tubers caused more impact to the tubers.

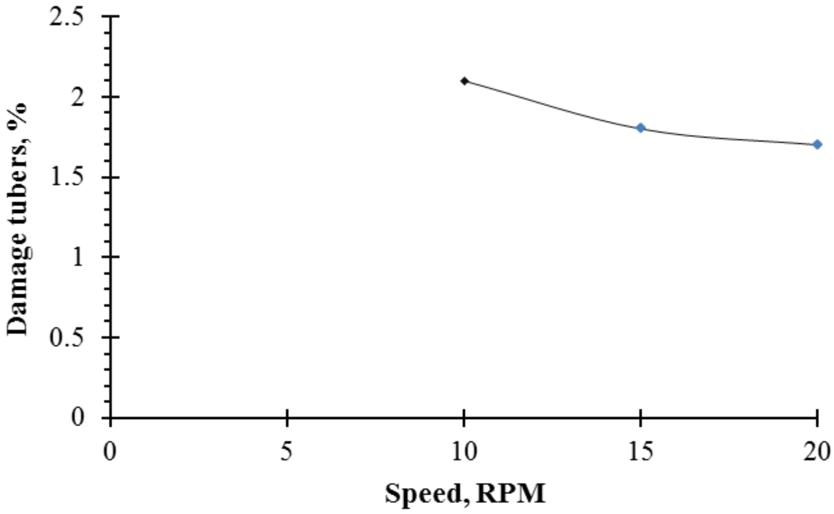

Figure 2. Percentage of damage tubers for each RPM of the grader

B. Influence of Inclination

Table 2 shows the mean values for the machine parameters as affected by the inclination of the grading unit. Highest grading system efficiency of 90.15% was observed at an inclination of 5 degrees whereas; lowest efficiency was obtained at an inclination of 15 degrees. Extremely high inclination caused immediate transfer of tubers to the next several gaps as caused by gravity plus the effect of the rotation of the spiral. Tubers in this scenario especially the smaller ones at the first region jump to the next selection region without passing to the succeeding region.

Table 2. Performance of the grader as influenced by the inclination of the grading unit

Machine parameters	Inclination (degrees)		
	5	10	15
Grading System Efficiency (GSE), %	90.15^{a}	82.68^{b}	74.47^{c}
Capacity, kg/hr	811.0^{a}	862.6^{b}	817.8^{c}
Damaged Tubers, %	1.992^{a}	1.858^{b}	1.771^{c}
Power Consumption	12.3^{a}	11.56^{b}	10.86^{c}

Means having the same letter along row are not significant

Damage tubers as influenced by the inclination of the grader were observed to decrease with higher inclination as shown in Figure 3. As shown earlier in Table 1, damaged tubers were observed to be influenced by the large amount of tubers in the grading unit along with very high RPM. The large number of tubers in the grading unit tends to create a heavier impact among each other during the rotation of the grader. For the inclination of the grader, it was observed that at very low inclination which is 5 degrees, there were more number of tubers damaged which is almost 2% of the total samples as shown in Table 2.

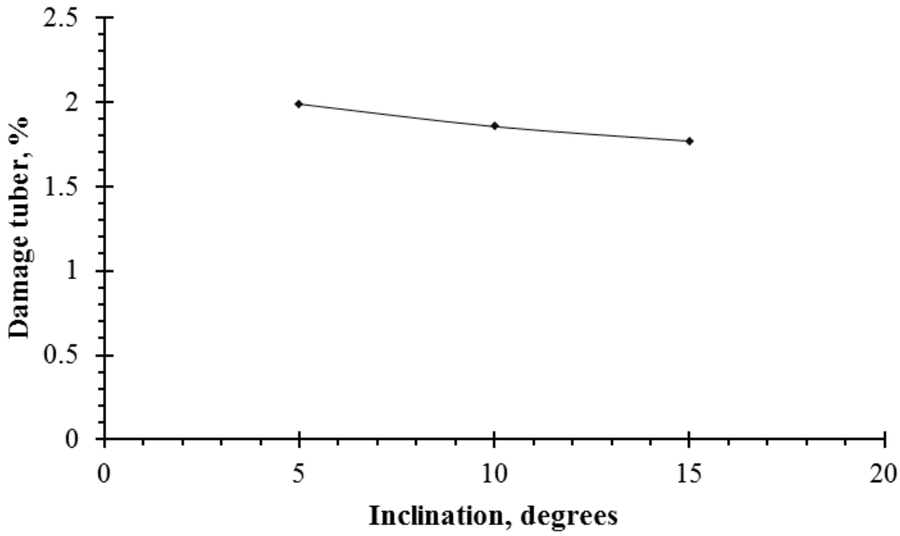

Figure 3. Distribution curve of the damage tubers for the inclination of the grader

C. Tubers characteristics after grading

Since the samples used in the evaluation have no initial damage, it was then easy to identify the physical impact of the operation to each of the tubers. Some tubers were observed to have abrasion after the operation. Tubers having abrasion of 5% or greater than the total surface area were considered damaged. The total number of the damaged tubers was expressed in percent to the total number of tubers in the samples prior to operation. There were no other significant mechanical damages such as cracks, removal of peels and bruises observed in the operation. The minimal damage in terms of abrasion observed could also be associated with materials making up the grading unit, since the metals were covered with a plastic pipe.

D. Break even analysis

The total cost of the potato grader was P31, 000.00 with an estimated life span of 5 years. It had an annual fixed cost of P8,215.00 and variable operating cost of P72.25/hr. Assumptions include: interest, 10%, tax, insurance and shelter, 3%, repair and maintenance, 15%, operation per day, 8 hr, annual use, 600 hr and custom rate P0.5/kg. The grader had a break-even point of 23ton/year. If available quantity of tubers is greater than the break-even quantity, the use of the grader will result to profit. Otherwise, the device is expensive to use when available quantity is less than the break-even quantity.

Conclusion

The optimum operating parameters for the machine was established at a speed of 15 RPM and inclination of 10 degrees with an efficiency of 92.56%, capacity of 883.16 kg/hr, less damaged tubers of 1.83% and a low power consumption of 11.3 W-hr. Compared to the findings of the previous version of this study, the grader had an optimum GSE of 94.5%, capacity of 550 kg/hr, damage tuber of 1.85%, and power consumption of 18.1 W-hr.

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