Design of shaker potato digger machine with collector

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Abstract

Agriculture covers around 70 percent of population activities in Rwanda with annual income of around 30 percent of GDP. Potatoes are the agricultural commodities that have the potential to be developed in Rwanda. However, during harvesting, simple traditional method was used, just using the hoe. The farmers are complaining for the easy harvesting method using less work force due to the farming labor costs which are getting increased day-to-day, and much time compared to the traditional method. In this paper, the shaker potato digger with collecting potatoes machine has been designed to overcome the farmer’s issues at affordable cost. It is a machine conducive to the environment. The machine parts were modelled and assembled in solidworks. And then, the analysis of its performance was done using solidworks simulation. The average manual harvesting efficiency of 82.2% is considered to be lesser than efficiency of 96.8% of the new designed machine. This can lead to the increment of harvesting efficiency of potatoes and reduction of daily man power. Therefore, the focus is to minimize all losses that occur when manually harvesting the potatoes and generally strengthening the agricultural.

Keywords: agriculture, harvesting, shaker, farmer and mechanization.
1 BACKGROUND

Mechanization of agricultural crops is at a very low level in Rwanda. Most of potatoes growing activities are manual requiring high amount of labors and hard work. Therefore, modern agriculture activities are needed to increase harvesting and reduce time spend and labors agriculture in Rwanda. This is due to high demand of foods at markets and it can help avoiding harvesting losses due to adverse weather conditions during harvesting. The saving in time in harvesting may be utilized for post-harvest processes to increase processing or consumption.

The harvesting process though mechanical assistance as introduced in 1800’s still relied on hand pickers to collect the crops and continued to do so until mid-20th century. The first mechanical potato digger was developed in England in the late 19th century by Verma, 1977. The small shaker potato digger the crops is picked manually in this study to design the shaker potato digger with crops collector. (Verma, 1977).

On the hand, in Rwanda for instance in KINIGI area, where potato production rate is high. The farmers are harvesting using the traditional tool called hoe as shown in Figure 1. This method of harvesting potato is widespread despite it needs a lot of labors, cost and time. On the other side; the large harvesting machines are uneconomical in those small areas (Culpin, 1981).

![Figure 1: Manual harvesting method (Culpin, 1981).](image)

The simple harvesters resemble side-loading elevator diggers, more complex models include more complex processes including electronic separation mechanisms (Varshney, 1989).

Potatoes roll down the separator toward a potato conveyor, while other flat or rough objects remain on the separator to be transported onto a stone and trash conveyor. There are two main machines in staged harvesting which are spinners and elevator diggers. The spinners that are available vary in type depending on the working conditions specifically and soil type. While trailed wheel-driven spinners as shown in Figure 2 are commonly used, tractor-driven models are more popular. (Vatsa, 1996).

Two off-center wheels that are joined by a linkage to which the tines are attached enable the tines to push the potatoes, distributing them sideways, enabling them to be picked up by hand. (Ynis, 1987).
The Elevator diggers, available in one or two-row models, are employed in areas where soil is not too dense or heavy (Verma, 1977). This study is going to develop and analyzed the performance of the shaker potato digger machine model.

Figure 2: Tractor-driven Spinners (Ynis, 1987).

2 Materials and Methods

The main specifications of the shaker and potatoes digger parts were gathered from the previous literatures.

The research are named Kinigi is situated at an altitude of 2,200m bordering Park National des Volcano in Northern Province. It is a sector of Musanze district with 5 villages with a total population of 22,271 habitants on a total surface area of 81.04sq.km which is 15.3% of the total Musanze district surface area. It is an area where farming of Irish potatoes is widely grown.

Camera has been used for taking photos, and data were recorded on sheet. Manual digging using spade was assessed and find out that the high labor intensive ranging about 100-135 men per hectare. Time consuming and sometimes the increase of damaged potato crop during harvesting was not figured out due to its fluctuation.

The parts of the machine have designed analytically and modelled using solid works software. Simulation has also evaluated using the solidworks and validated with previous researches. This article has used the survey design. Therefore, this section has been focused on the following: design of digger blade, design of shaft, design of main flame, design of rocker arm, connecting rod and vibrating riddle/ Separating unit.

2 METHODS

a. Main frame: The designed frame (Figure 3) has a rectangular shape made in angle bar from AISI 1035 steel (ss) with 7850kg/m³, and Elastic Modulus of 205000Mpa. The frame is with length of 100cm, 60cm in width with, 50cm height above the ground excluding wheel.
b. **Shaft:** The mild steel shaft designed for power transmission considering bending moment, axial load, and torque acting on. It is 30 mm diameter and 300mm long. The shaft has been designed under the following parameters as shown in Table 1.

Table 1: Designing parameters

<table>
<thead>
<tr>
<th>S/N</th>
<th>Name</th>
<th>Maximum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bending Moment</td>
<td>166Nm</td>
</tr>
<tr>
<td>2</td>
<td>Speed</td>
<td>1435rpm</td>
</tr>
<tr>
<td>3</td>
<td>Velocity</td>
<td>413.3mm/s</td>
</tr>
<tr>
<td>4</td>
<td>Torque</td>
<td>166Nm</td>
</tr>
<tr>
<td>5</td>
<td>Stress</td>
<td>36.94N/mm²</td>
</tr>
<tr>
<td>6</td>
<td>Shear stress</td>
<td>0.044N/m²</td>
</tr>
<tr>
<td>7</td>
<td>Factor of Safety</td>
<td>1.5</td>
</tr>
</tbody>
</table>

c. **Digging blade:** The digging blade is a passive flat- rectangular blade with concave edge. The digging blade is made of ductile iron of E=120000 Mpa with 25cm length, 58 cm width and 2 mm thickness as shown in Figure 4.

d. **Collector:** It was found that manual picking is very tedious and boring work. This is the rear part of the machine and was used to collect the potatoes as shown in Figure 5.
**e. Pulley**: The pulley (Figure 6) was of 70mm and 425mm of diameters for small and large pulley respectively. The distance between centers was 210mm. The corresponding speeds are 1435rpm 236.35rpm for the two pulleys respectively, where the small speed is the same as the speed of the shaft. The center distance between pulleys is 10mm, length of 1498. 6mm and the corresponding length of belt is 1741.5mm.

**f. Design of digger blade**:  
In most designs of potato harvesters, the value of $\alpha$ has found to be $(25^\circ - 40^\circ)$ at depth $H$ of $(180\text{mm} - 250\text{mm})$.

In Rwanda, the potato tubers maturation occurs at depth $H=25\text{cm}$ and we assumed clearance of $\Delta=5\text{cm}$ and $L_0=60\text{cm}$. Therefore, for the present case $\alpha = 30^\circ$ shown in Figure 7. (Icengine, 2010).

**Figure 5: Shows design of collector**

**Figure 6: Pulley**

To determine the load affected on digger blade. First, volume of the soil in the digger. It was assumed the volume of soil of $0.15\text{m}^3$.

Weight of the soil on the digger of $10153.35\text{N}$ and then, the moment applied on the digger blade is  

$$M = 10153.35 \times 0.58 = 5888.94\text{Nm}$$

**g. Design of separator**

Table 2 shows the diameter of rods $d_r$ and clearance between the rods $S_r$ can be calculated by the following:  

$$d_r = 10.5 \approx 10\text{mm}$$

<table>
<thead>
<tr>
<th>Group No.</th>
<th>Tuber Weight (M) gm.</th>
<th>Tuber Length (L) mm.</th>
<th>Tuber Width (W) mm.</th>
<th>Tuber Thickness (H) mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30-50</td>
<td>38-58</td>
<td>37-45</td>
<td>29-39</td>
</tr>
<tr>
<td>2</td>
<td>50-80</td>
<td>51-64</td>
<td>41-57</td>
<td>32-47</td>
</tr>
<tr>
<td>3</td>
<td>80-120</td>
<td>56-77</td>
<td>42-56</td>
<td>38-49</td>
</tr>
<tr>
<td>4</td>
<td>30-120</td>
<td>38-77</td>
<td>37-56</td>
<td>29-49</td>
</tr>
</tbody>
</table>
However, great values could cause accumulation of soil and tubers on separator surface. Speed of separator is $V_c = 3.7\, \text{m/s}$. By using suitable scare for space diagram. The required speed of separator is $3.88\, \text{m/s}$ as equivalent to as of digger.

**h. Design of collector:** Potato container made of steel rods with 60mm long and 70mm in width. This was provided to make ease picking and gathering scattered potato during harvesting. Theoretical field capacity of the machine is 9m/min of travel speed of man’s normal walking m/min. Total feed rate of tubers $Q_t$ is 36kg/min. The harvesting efficiency can be calculated was 96.8%. Collecting efficiency can be calculated by the following equation $81.2\%$. Manual digging efficiency can be calculated by the following equation $82.2\%$.

**Power of cutting soil**

\[
\text{Power requirement to cut and lift soil} = \frac{2895 \times 25}{60} = 1.2\, \text{KW}
\]

Where $v_{\text{travel}}$ is the travel speed of the machine.

### 3 RESULT AND DISCUSSION

The potato digger cum elevator should work better at an elevated height of 25cm. It was observed that, there is no bouncing of tubers on the separator. While during digging, the damage, bruising loss and cutting loss were supposed to be less. And whereby the digging efficiency is more at 96.8\%. This study has also focused on evaluating the performance of the tractor drawn under four forward speeds of 1.40, 2.30, 2.95 and 3.50 km/h, three blade rake angles of 10°, 14° and 20° and three digging depths of 25, 30 and 35 cm. Taking into consideration the machine actual capacity, product losses, harvesting efficiency, cleaning efficiency, and required energy. It has been also based on criterion cost of harvesting comparing with the manual method of harvesting (Hand hoe method), to achieve actual field capacity of 0.23 fed/h.

The lowest percentage of total losses including:

- 2.90% for the damaged tubers
- 1.20 % for the un-harvested tubers,
- High harvesting efficiency of 97.50 %,
- The highest cleaning efficiency of 95.32 % at required power of 16.42 kW and specific energy requirement of 71.39 kW.h/ fed.
4 CONCLUSION
Growing of potatoes in Northern Province of Rwanda is one of the big business as the harvest can export in other countries. The traditional method of growing potatoes doesn’t give much income to the farmers. The average manual harvesting efficiency of 82.2% is considered to be lesser than efficiency of 96.8%, which is produced by using developed machine. The machine can help in saving about 75% labor and operating time, and 50% on the cost of operation compared to conventional method of manual digging, with forward speed of the digger of around 3km/hr. The tractor can have the harvesting efficiency of 97.50% and cleaning efficiency of 95.3%”. The future research can go beyond one raw machine as this will have good impact in growing the potatoes in the northern region of the volcanic soil.

5 LIST OF ABBREVIATIONS
IST: Institut Superieur de Technologies

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AC: Alternative Current
PTO: Power Take-Off

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