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RESEARCH ARTICLE

DEVELOPMENT AND EVALUATION OF CARROT WASHER TO IMPROVE FARM PRODUCTIVITY THROUGH MECHANIZED APPROACH

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ABSTRACT

Food crops a vital part of human nutrition because the main need of vitamins and calories in a large portion of population is met by food crops. There is an enormous demand of food in Pakistan due to its increasing population. This demand of food can be conquered by introducing an innovation in the market, so that output could be achieved by less in economical range. Agricultural machines play central role in crop productivity, when planting and harvesting. A carrot washer is a machine that could be useful in agricultural mechanization. To increase market value, root crops such as carrot must be cleansed of soil particles after harvesting and before being transported from field to market. Carrot washing is mostly done manually with brooms and feet, using un-cleaned water from a nearby spring. Manual cleaning must require labour and takes time due to the sticky muck on the surface of the carrot. With a cleaning effectiveness of 98%, carrot washing is a highly handy cleaning machine. It can also be used to wash other crops after harvesting, such as potatoes and radishes, so that they can be transported to markets. This is a low-cost machine that is affordable to any farmer in Pakistan. The purpose of this research is to go through the design and details of this carrot washer. The machine comprises a wooden drum with a constant supply of pressurized water. After harvesting, muddy carrots are inserted inside the drum through an entrance in the drum's face. The wooden drum rotates and scratches away foreign material from the surface of the carrots, while pressurized water is used to wash away the soil. After washing, the wastewater drains from the drum via slots around the circumference. As a result, carrot washing cleans carrots and other root crops and prepares them for commercialization. This machine can also be used to prepare other root crops for market by washing them. Tucky test was used to analyses the observations. When compared to the traditional way of washing, the machine showed to be more time efficient. The cost of manually washing carrots is estimated to be around Rs. 1000 per hour, while the cost of operating this equipment is only Rs. 364 per hour. Manual washing takes time as well, but using a carrot washer saves time when compared to manual washing. Carrot washing takes 80 hours per acre per person in conventional washing. However, the same work can be completed in 15 hours. In short, it may save around 65 hours per acre, is simple to operate, and ensures safe carrot handling. Aside from carrots, it can also be used to wash other root crops

KEYWORDS

Muddy Carrots, Carrot washer, Tucky Test, Mechanization, Centrifugal Pump (CP).

1. INTRODUCTION

Vegetable growing is a labour-intensive industry that can assist produce jobs in the rural economy. As a result, it is a multifaceted activity that can benefit the economy in a variety of ways like high nutritional, high yield, higher return moreover highly labor-intensive attributes (Tahir and Altaf, 2013, Abedullah et al., 2006). Punjab's soil and climatic conditions are ideal for vegetable agriculture, and a variety of vegetable species are grown. Punjab province has a higher share of total vegetable acreage and production than other provinces, estimated to be over 60% and 67%, respectively. (Khokhar, 2014). Potato has the highest area share (34.01%) among the vegetables grown in Punjab. Onion is ranked as the 2nd important vegetable with the area under cultivation of approximately 8.87% of total area covered by vegetables in Punjab. The carrots have a share of 2.67% in the area of Punjab (Ahmad et al., 2005). According to estimations Punjab province has 65 percent of the entire area under carrot cultivation in Pakistan and produces 68.4% of total carrot production.. Carrot (Scientific name: Daucus carota varsativa) is categorized under biannual crops. The French word carrotte is derived from a Latin word *carrota*; it means a perennial plant which is cultivated broadly due to its long conical shaped orange root that is used as food Carrot belongs to genus Daucus. This genus is comprised on 25 species and is known as the biggest genus in the Umbelliferea family (Rubatzky et al., 1999).

Different factors affect the carrot production like temperature which affects the quality, yield and growth of the carrot in different ways. Another parameter like growth parameter among other includes plant height, leaf number and leaf growth. Root fresh and dry mass also include in yield parameter. Carrots Quality is classified into two parameter like external parameter and internal parameter. The external quality

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parameters are comprised on the color, root length, absence of defects and diameter on the other hand characteristics like sensory quality, terpene contents, sugar carotene and firmness are included in the internal quality parameters (Rubatzky et al., 1999). The harvesting of carrots is done by both manual and mechanical methods. In Pakistan manual harvesting is generally done for carrots. The harvested carrots still require some further treatment it can be passed to the consumer. The post-harvest practices for carrots are generally comprised on washing, cleaning, grading, sorting, storage, packing, transportation and marketing. Carrots are easily damaged during pre-harvesting and post-harvesting practices same as other vegetables. The carrots continue to respire even after harvesting. This makes them more viable to post-harvest damages. These damages can only be minimized by utilizing proper techniques for packaging of carrots.

Fruits and vegetables are highly perishable. Nearly 23 % of most perishable fruits are lost due to water loss, physiological decay, mechanical damage and spoilage during their journey through the agricultural food chain. These losses usually occur during harvesting, transportation, processing and packaging processes. In tropics and sub tropic regions, these losses can go beyond 50 percent. Microbial food hazards can be minimized to a great extent through proper washing of the fresh products. This process is very helpful because most of the microbes are present on the outer surface of the fruits and vegetables. Fruits vegetables are prewashed to get rid of immediate surface dirt and pesticide residues before any leaves and stem still attached are removed. It is recommended that fruits must be cleaned after harvesting to improve product look and edibility by removing residues of field-applied pesticides and hazardous bacteria that would decrease the product's life. According to Walker (1996), mechanical surface cleaning systems can be used to remove mites and several surface arthropods mainly through rotating brushes and high-pressure water sprays. He also suggested that the surface arthropods are usually removed by using spray that ranges from (2240 to 5516 kPa). As per an investigation, on an average 79 percent of total farmer community of Pakistan holds under land farming of 5ha (GOP, 2022). In Pakistan, farmers have small portion of land for different crops cultivation, the income can be improved by growing flowers and vegetables. Vegetable products became more famous because of their higher yield capacities, higher return, more nutritional value, appropriateness for farmers having small area and less cropping period. Pakistan contains more than 35 different types of vegetables that are being grown in various locales of nation. In perspective of degradation of land, increase in population and because of shortage of water, cultivation of vegetables should be increased.

1.1 Problem Statement

Carrots must be cleaned after being harvested from the farm and transported to the market. Small-scale farmers in Pakistan are not accustomed to cleaning gathered carrots. This is mostly owing to the lack of proper mechanised methods of cleaning harvested root crops. Most farmers/traders in Pakistan utilise a traditional method to clean their harvested carrots, which involves manually washing the carrots with a metal sponge, water, and a preservative such as potassium permanganate or salt. did a case study in the Asante Mampong municipality, and he indicated that traders employed traditional methods such as washing and scraping or washing just for the processing of carrots (Asamoah, 2012). According to the findings, 84% of carrots were washed with a metal sponge, 14% using a brush to scrape, and 2% with bare hands. Because washers are expensive. Aside from being challenging and time consuming, these procedures tend to contaminate the carrots, particularly when a metal sponge is used. For these reasons, we investigated a mechanized method of constructing a low-cost carrot washing machine. The proposed design will assist farmers in reducing the time spent washing harvested carrots, the expense of labour used to wash harvested carrots, and the risk of contaminating harvested carrots with stones, metal sponges, and other items during hand washing.

2. Materials and Methods

According to request of the farmers that grow the root crops, it was needed to fabricate a machine that could help in cleaning of root crops at farm. AMRI, Multan has developed and fabricated a machine for the farmers that grow root crops. The machine was operated and evaluated in field. The performance evaluation of machine was done on the basis of capacity of machine and washing efficiency. The working mechanism of machine is mainly composed on the rubbing action produced on carrots with the help of brushes and wooden strips in the washing drum.

A medium size machine was designed and developed for washing of carrots. Washing efficiency and capacity of the machine was tested in the field. The working principle of petrol engine operated carrot washer is the rubbing action produced between the carrots and the brushes mounted inside the washing drum. The main parts of the carrot washing machine are the washing drum, water trough, main frame, petrol engine, spraying system, washing drum supporting rims, pulleys, nuts, bolts and screws. The washing drum is made of wood strips of dimensions 2438 mm length, 610 mm diameter, 25mm thick, 75mm wide and 23 wooden strips with spacing of about 4mm to 8mm between them as an opening for contaminated water and there is a spraying system of M.S pipe of diameter 25mm with hole diameter ranging from 2 to 3 mm with spacing between two holes is 50mm which provides pressurized water onto the carrots in the washing drum. Wash drum supporting rims are used to provide guide to the wooden strips to keep them in circular position with the help of screws to hold wooden strips. Water is entered from the centrifugal pump by means of inlet pipe to take water from the water course and entered in the machine by means of sprayer pipe of 25mm diameter is provided with non-return valve. The Spurger pipe has holes, running along its length, having diameters ranging from 2mm to 3mm drilled on it for spraying. The holes are used in place of nozzle to minimize the cost of design. Carrots are feed in the wash drum through loading tray and washed carrots after washing received on the other end of wash drum. Washed carrots are than packed in bags for sold in the market. The discharge water collection tank is located below the washing drum for the collection of contaminated water. Contaminated water is drained in the water course by mean of drain pipe of size 3 inch.

The system is design in such a way that excess water can be controlled and re-used for other purposes such as irrigation. The washing drum rotates freely by means of a wash drum supporting reels. Rotation of the drum controlled by the petrol engine which delivers powers to the washing drum through V-Belts and pulleys of size 304mm and 100 mm. The whole system is supported by the frame which is made of iron angle of dimension 38 x38 x5 mm and M.S sheet of thickness 3 mm. The total dimension of main frame is 4000 x1066 x1800 mm. Main frame is provided with two wheels and hitch for the purpose of transportation in the field.

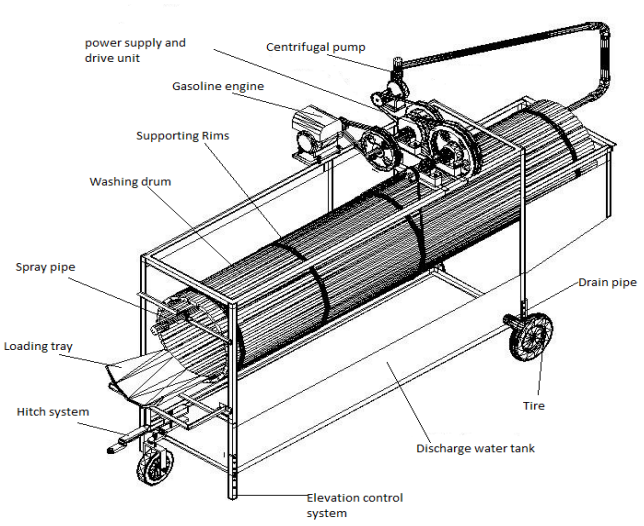

Figure 1: Main components of carrot washer

2.1 Power Transmission and Drive Unit

Carrot washer was operated by a Petrol engine having 2250 rpm. To obtain the required rpm of washing drum different sizes of pulleys (12", 10", 8", 2.5" and 3.5") are be used. The power of petrol engine is diverted to the round wooden washing drum of carrot washing machine and centrifugal pump with the help of V- belts and pulley.

2.3 Water Supply Unit

Perforated/ Spray pipe was used to add water from the water course with the help of centrifugal pump into the washing drum with pressure and remove foreign material/ soil from the carrots after rubbing with wooden strips and brushes installed in the wooden wash drum at different angles. Figure 3.7 and 3.8 show the water supply unit and location of washing brushes with their exact position and spray angle inside the round wooden washing drum. Spray pipe has hole of about 2 to 3 mm with spacing between two holes are 50 mm.

The bruise index was directly proportional to the operating speed for washing of carrots. Damage Index is a degree of damage of tubers during

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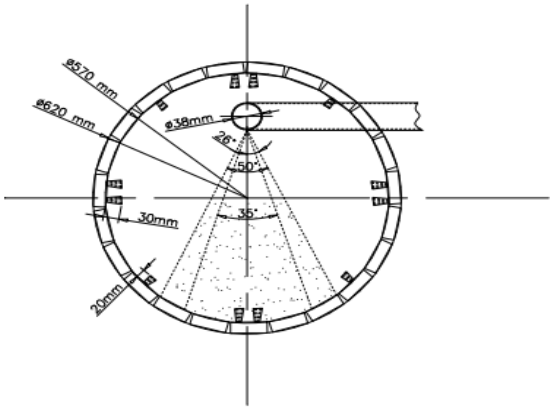
cleaning. D. I (damage index) is a physical damage during grading. The utilization of spray washer for cleaning of vegetable is most effective technique.



2.4 Discharge Collection Tank

Discharge tank is rectangular in shape made up of Mild steel sheet of 3 mm thickness and Angle iron of dimension 25×25×3 mm. It is used for the purpose of holding water after washing. Water after washing of carrots falls down in the discharge water tank through the spacing in the wooden strips of washing drum and collected water in the discharge tank are drained out in the water course with the help of drain pipe of size 3 inch. In this way we can save water for agriculture purpose.

2.5 Design Calculations

Washing Drum Volume = $\pi \times r^2 \times L$

$=3.1416 \times (280)^2 \times 3048$

$=3.1416 \times 78400 \times 3048$

$= 750726789mm$

Equation was used to compute the volume of the wash drum.

L= length of the wash drum.

r = Radius of the wash drum.

Discharge Tank Volume = L×W×H

2.6 Cleaning Efficiency

Cleaning efficiency is defined as the ratio of carrots washed efficiently to carrots fed to the carrot washer for washing. It can also be determined by using equation 3.3.

$$\text{Cleaning Efficiency} = \frac{Quantity\ of\ carrots\ washed}{\text{Total number of carrots in the washing drum}} \times 100$$

2.7 Washing Efficiency

The ratio of washing efficiency is the weight0of carrot before0washing to0the0weight of carrots0after0washing. Washing efficiency can0be0calculated by using equation 3.4.

$$\text{Washing Efficiency} = \frac{\text{Weight of0carrots 0before washing}}{\text{Weight of0carrots0after washing}} \times 100$$

2.8 Damage Percentage

Damage percentage is the ratio of damaged carrot to the total number of carrots after washing.

Damage percentage can be calculated by the following formula.

$$\text{Damage percentage} = \frac{damaged\ carrot\ after\ washing}{total\ number\ of\ carrots\ after\ washing} \times 100$$

3. Results and Discussion

The0carrot washer0was tested under different field0conditions and data0was0collected0carefully to0check0the performance0of carrot0washer. On0the basis0of these0tests, suitable0dimensions of the0carrot washer0were0suggested. The results0obtained at0different0field conditions0are presented0statistically0in table. Table0consist0of0different type's of0washing drum0having different0lengths, slope, average cleaning0capacity in0kg/hr and0finally0average0cleaning efficiency0of carrot0washer at0different0slopes and0lengths. Statistical0analysis of data0shows that there0was a significant difference0in the performance0of carrot washer0under changing0parameters. There0was a0significant difference0in the cleaning0capacity and0cleaning efficiency0of the0carrot washer having0washing drum0of same0length at0different slope0also there0was a significant0difference in the cleaning0capacity and cleaning0efficiency at0same slope in0washing drums0of different0length. Firstly, when0the drum $d_1$0was used0its cleaning0capacity was more0at slope02.25%0as0shown in0table but cleaning0efficiency was0more at that slope but cleaning capacity was less, so0d_1 is replaced0with0d_2 but d_2 also0gave0the same0results0as d_1. Now0we introduced cleaning0brushes in0d2 and named0it as0d_3. On testing0d_3 at different0slopes the results0were0excellent. At 75%0slope the0cleaning efficiency0was maximum0but cleaning0capacity was less0and0at 2.25% slope0the cleaning0capacity0was maximum0but cleaning0efficiency0was minimum. In0this study0our main0concern was0on cleaning0efficiency0so the0recommended0washing0drum0is d_3 at0slope 75% as0it gives0maximum cleaning0efficiency at0this slope. All0the0statistical results0are shown0in0table.0

Table 1: Machine Performance on Different Slopes in Different Washing Drums

The influence of slope and drum length	Parameters	
	Drum washing capacity (kgh^{-1})	Cleaning Efficiency (%)
Drum length (ft)		
D1=6	1324A*	74.2C
D2=10	1192 B	82.0 B
D3=10 + brushes	1090C	92.3 A
Slope of drum (%)		
S1=0.75	1138C	87.9A
S2=1.50	1197B	84.0B
S3=2.25	1272A	76.7C

Table 2: Drum length and slope interaction

Drum Length	Slope of drum	Washing capacity of drum (kgh^{-1})	Cleaning Efficiency (%)
6 ft	0.75	1249d	78.7e
	1.50	1326b	75.0f
	2.25	1398a	69.0g
10ft	0.75	1115g	87.0c
	1.50	1193e	83.0d
	2.25	1269c	76.0ef
10ft with Brushes	0.75	1050i	98.0a
	1.50	1071h	94.0b
	2.25	1150f	85.0cd

Values in the same column followed by the same letter for each effect are not statistically different (P≤0.05); significant value based on Tukey's test.

Table 3: Time taken by labors and the machine to wash carrots

Number of carrots	Time taken to wash carrots by labors		Average time (second) taken by labor	Time taken to wash carrots by machine
	T1	T2		
10	60	75	67.5	39
20	140	170	155	56
30	149	180	164.5	59
40	223	260	241.5	60
50	271	310	290.5	66
60	310	365	337.5	69
70	351	408	379.5	71
80	384	440	412	73

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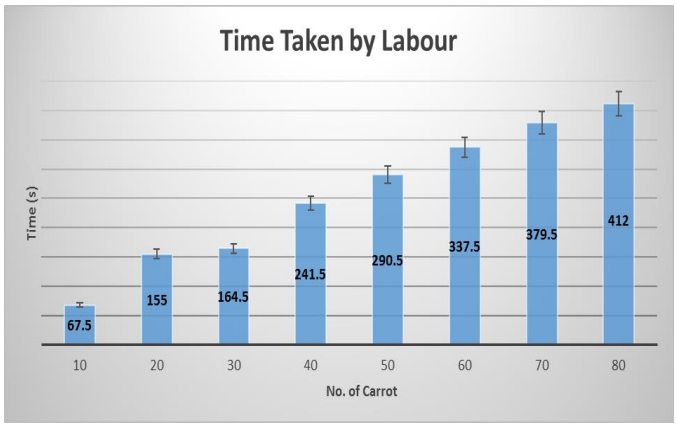

Figure 2: Time taken by labor vs. feed

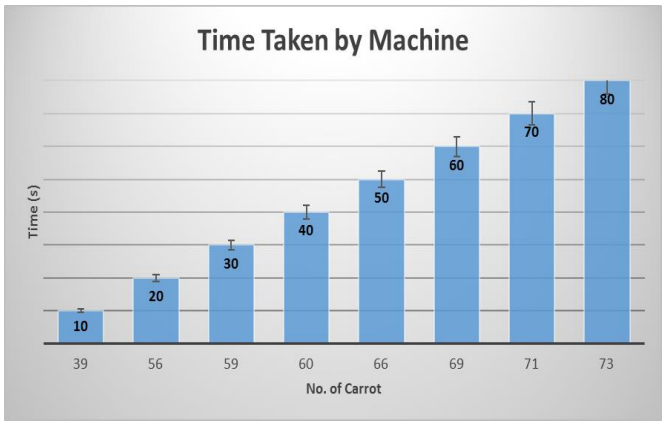

Figure 3: Time taken by machine vs. Feed

4. Testing for Efficiency

Before placing carrots into the carrot washing machine to be washed, their original weights had been calculated. Using an electronic balance this task was carried out at the Agricultural Mechanization Research Institute (AMRI). The weights were determined again after washing by means of the carrot washer and the relevant efficiencies are reported in table 4.4.

Figure 4: Sample of unwashed carrots

Table 4: Washing Efficiency at different feed

Number of carrots	Weight before washing(g)	Weight after washing (g)	Washing Efficiency
10	152	135	89
20	244	224	92
30	358	338	94
40	473	452	96
50	610	589	97
60	750	736	98

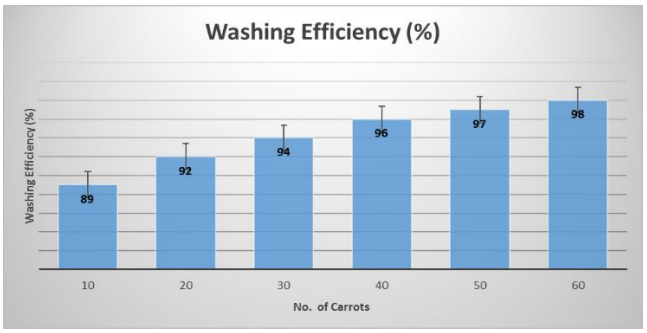

Figure 5: Washing efficiency against feed

5. Effect of Drum Speed on Washing Efficiency

The carrot washing machine's washing efficiency was measured by adjusting the drum Speed to 30 rpm, 35 rpm, 40 rpm, 45 rpm, and 50 rpm. Higher efficiency (97.4%) was achieved for 40 rpm while lesser efficiency (89.1%) was measured for 30 rpm. It was additionally discovered that when the drum speed had been adjusted to 50rpm, there were also minor damages.

Table 5: Effect of drum speed on washing efficiency

Revolution per minute (Rpm)	Washing efficiency (%)
30	89.1
35	96.8
40	97.4
45	98.4

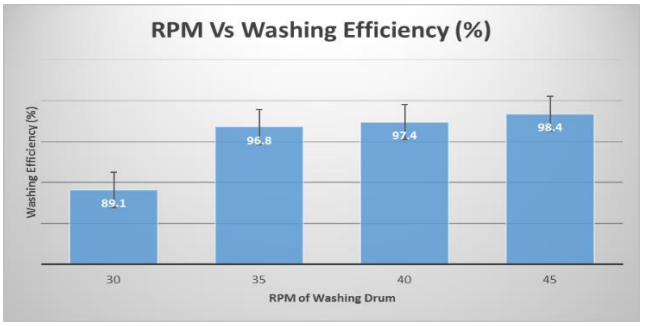

Figure 6: Washing efficiency against RPM of Wash drum

6. Damage Percentage

The damage percentage of a self-propelled carrot washing machine was determined by varying the drum speed to 30, 45, and 50 RPM with the same amount of carrots. It was observed that damage percentage is higher at 50 rpm and lower at 30 Rpm.

Table 6: Effect of RPM of Washing Drum on Damage Percentage

Number of carrots	RPM of wash Drum	Number of carrots break	Damage percentage
1600	30	50	3.125
1600	45	70	4.375
1600	50	80	5.0

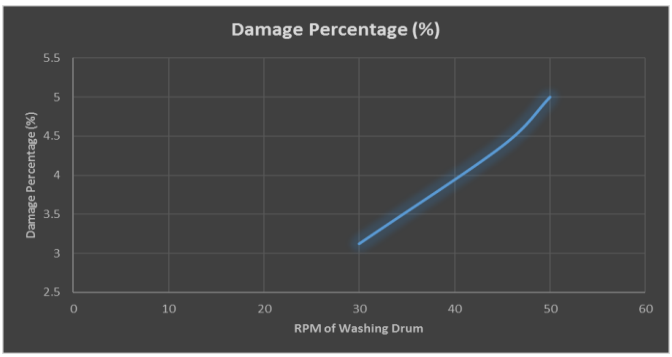

Figure 7: Damage percentage with changing RPM of washing drum

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7. Cost Analysis

To select a machine to perform a specific function or task its cost analysis is very important because the economic analysis of the require machine play a crucial role in trend of adoption by the local farmers. In this research the cost analysis of Self-propelled carrot washer machine and its comparison with manual washing to evaluate the economic possibility. From the research it was concluded that by using self-propelled carrot machine farmers can save about Rs. 635.76 h-1. Following sub-section gave the brief detail and discussion.

8. Estimated Price of Self-propelled Carrot Washing Machine

8.1 General Facts

Estimated cost of self-propelled carrot machine, P = Rs 77500

Salvages values, S (usually taken as 0.1 of P) = Rs 7750

Probable machine life, (h) = 10 yrs

Machine usage per year, (h) = 540 hrs

Whole life of the machine, (h) = 5400 hrs

8.2 Fixed cost

Fixed cost is those which cannot be changed and deprecation, insurance, repair and maintenance and interest. Following relation was used to find out depreciation.

$$\text{Deprecation} = D = \frac{\text{Purchase value(P)} - \text{Salvage value(S)}}{\text{machine estimated whole life(L)}}$$

Where,

D = Cost of depreciation (Rs/hour)

P = Machine purchasing cost (Rs.)

S = Price of salvage (0.1 of P)

L = Machine estimated whole life (years)

$$\text{Deprecation} = D = \frac{77500 - 7750}{10}$$

= Rs. 6975

As expected, life of the machine is taken as 10 years so, salvage = 10% xz

$$\text{Interest @ 11 \% of P} = 0.11 \times \frac{77500 + 7750}{2}$$

= Rs 4688 /year

Insurance and cost of housing is taken @ 0.03% of purchase price = 2325/year

Total fixed cost = 6975+4688+2325

= 13988/year

Supposing the use of machine is 540 hrs/years

Estimated fixed price/hour = Rs 25.72

8.3 Variable Cost

It includes the cost which would vary with time. It includes repair and maintenance which might be taken @ 15 % of purchase price = 0.15×77500

= Rs 11625 per year = 21.52 rupees / hr

Labor cost for 2 labors = Rs.200/hr

Usage of fuel per hour =1.3 L/h

Fuel price @ 90/L =Rs. 117

Total variable cost = 21.52+200+117

= Rs 338.52 h-1

The whole price of carrot washing machine is

Entire price (fixed price + variable price) = 25.72 + 338.52 = 364.24 rupees/hr

8.4 Manual Washing

Labour Require for manual washing =6 person

Labour cost for 6 hrs=1000 rupees/person

Labor cost for 6 labors = Rs.1000/hr

Manual wash of 120 Bags of carrots=6 hrs

Cost on manual washing=1000 rupees/ hr

8.5 Washing by Machine

Labour require= 2 person

Labour cost for 6 hrs = 600/person

Labour cost for 2 labour =200/hr

Machine washing of 120 Bags of carrots = 2 hrs

Cost on machine washing = 364.24 rupees/hr

8.6 Benefit By Machine Washing

Benefit = manual washing – machine washing

Benefit = 1000-364.24 rupees/hr

Benefit =635.76 rupees/hr

8.7 Cost Benefit Ratio

Benefit/Cost = 635.76/364.24

Benefit/ Cost =1.745 rupees

Payback period=122hr.

9. Discussion

Washing is a cleansing and sanitization process that involves dipping, rinsing, rubbing, or scrabbling. It is crucial in agricultural processing because it adds value while also increasing the quality and safety of the produce in post-harvest operations. Washing carrots is required in order to effectively weigh, classify, and grade them. Soaking in still water, moving water over the product, spraying water on the product, brush washing, hot water, and shuffle washer are some of the principles employed in agricultural product cleaning.

In the realm of agricultural processing, there are two main methods of washing produce: immersion and non-immersion. Immersion washing involves submerging or floating the produce in water, while non-immersion washing entails spraying or rinsing the produce in a basket, wash bed drum, or barrel washer. The efficacy of the washing process is directly related to the amount of cleaning solution utilized. The processing of agricultural products is a vital step in converting raw harvests into valuable commodities for the market. This transformation serves to reduce waste, enhance product quality, bolster food security, and more. By increasing the volume and number of finished products and improving their overall economic value, agricultural processing can significantly increase the yield derived from raw farm products. To achieve this, various unit processes such as cleaning, sorting, grading, and size reduction are necessary, with the cleaning operation playing a crucial role.

The muddy carrots after harvesting from the field are fed in the round wooden washing drum through the loading hopper provided at one side of the washing drum. Centrifugal pump is used to regulate the spray of the water onto the carrots with the help of water spraying system that is attached on the top inside the wash drum. In the case of immersion washing, the trough/discharge water tank beneath the drum is filled with a sufficient amount of water so that when carrots are placed in the drum, they come into contact with the water in the trough/discharge tank. But in our case of study as this is non-immersion type of washing, wash drum is not dipped in the trough/ discharge tank filled with water. In both methods, the drum is set to rotate by gasoline engine. The rotation of the drum causes carrots to move to and fro within the drum and brushes installed on the strips inside the washing drum. There is a water spraying system that cleans the carrots from soil and other foreign materials. Carrots after washing is collected on the other side of the washing drum with the help of unloading tray.

Carrots must be cleansed of soil and other foreign particles after being

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harvested from the field before being processed or sent to market. Farmers in Pakistan currently employ the traditional practise of washing carrots by hand. To provide the best answer to this problem, a motorised carrot washing machine was designed. The carrot washing machine is made out of a circular drum made of hardwood strips and a steel centre pipe with holes bored in it for water spraying. The carrot washing machine was put to the test in the agricultural field against manual washing, and the machine proved to be more time efficient. The ideal drum rotation was found to be 40 to 45 rpm, and the washing capacity was 25 to 30 mond/hr. The machine's performance trial revealed that the average washing efficiency is around 98%. This machine can also be used to prepare other root crops for market by washing them.

10. Conclusion

The developed self-operated carrot washer has a capacity of approximately 25-30 mond/hr and was discovered to be useful for washing root crops such as carrot and raddish. The washer was tested in a farmer's field close to the Agriculture Mechanization Research Institute. (AMRI). Increasing the speed of the drum above 50 rpm increased fuel consumption, energy waste, and damage percentage. When compared to the traditional way of washing, the machine showed to be more time efficient. The cost of manually washing carrots is estimated to be around Rs. 1000 per hour, while the cost of operating this equipment is only Rs. 364 per hour. Manual washing takes time as well, but using a carrot washer saves time when compared to manual washing. Carrot washing takes 80 hours per acre per person in conventional washing. However, the same work can be completed in 15 hours. In short, it may save around 65 hours per acre, is simple to operate, and ensures safe carrot handling. Aside from carrots, it can also be used to wash other root crops.

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