Development of a manually operated root crop washer

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Root vegetables like carrot, raddish etc. need to be pre cleaned before transporting from field to market. At present there is no primary processing equipment like vegetable washers available for small farmers. A batch type, small vegetable washer with holding capacity 10 kg was developed for washing root vegetables like carrot and raddish. The washer consists of a detopper, a stainless steel washing drum, centre shaft with holes for water spraying etc. The washing drum was provided with different matting namely 5 mm thickness rubber, 1.5 and 3.5 mm thickness plastic, respectively for effective cleaning of the vegetables. Performance trials showed that, the washing and cleaning efficiencies were 97 and 91% for carrot and 96 and 90% for raddish, respectively using 3.5 mm thickness plastic matting.

Key words: Vegetable washer, carrot, raddish, washing efficiency, cleaning efficiency.

INTRODUCTION

Washing is one of the primary unit operations for value addition of horticultural produce at farm level. Washers may be continuous or batch type. Batch type washers are recommended for small plants where use is intermittent and operating costs are not critical. Soaking in still or moving water is effective only if dirt or other surface undesirable is present in small quantities and is loosely attached to the product. Water sprays vary from low pressure wide angle to very high pressure directed jets and are very effective since they physically remove firmly attached pieces of dirt and agitate the mass of product, particularly if it is carried in a water bath. Sprays are suitable for most products, but the intensity and type of spray distribution must be carefully selected. Flood washing is done by a large quantity of water moving at a moderate to high speed over the product (Henderson and Perry, 1976). Vegetables are washed in fields using a water jet delivered from a hosepipe and immersion soaking. These methods demand more labour but washing efficiency is very low due to non removal of thin layer of surface mud coating. So there is a need for and efficient washer to remove the mud and other foreign matter present on the surface of the vegetables, more specifically for root crops (Murray and Judy, 1996).

Vegetables are washed thoroughly to remove particles of soil and micro organisms that are present in soil. Vegetables may be contaminated with Escherichia coli and hence they should be lifted from water rather than water poured or drained off, in which case soil remains in the container with the vegetable (Charley, 1982).

Root vegetables like carrot, radish grow on heavy soils which are more rough and coarse. As the above vegetables grow under the soil they are well prone to mud and dust. These crops are manually harvested with leaves at the top to minimize damage while handling. They can easily be contaminated with microbial actions, physical damage, cracking cuts, bruising etc. They cannot be stored along with soil for a long time. It is necessary to wash off the mud and dirt particles which would reduce the physical appeal in the market and also aid in further processing. Relatively little information is available in the research literature on mechanical root vegetable washers for small farmers. Conventional washing methods for carrots, consisting of rotary washing systems in which carrots are not immersed, tend to damage carrots (Le–Bohec, 1993).

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Washing of vegetables by means of washer spray is the most satisfactory method. A product that is heavily contaminated with soil should be thoroughly soaked in water to loosen the soil before passing it under sprays (Antony, 1987). A low damage sugar beet cleaning screen was fitted with two types of polypropylene fibre brushes, a rotating cylindrical brush and a flail type strip brush. It was found that the brushes left less residual dirt on the beets and caused less damage to the root tissue than conventional cleaning methods (Moden et al., 1989).

In the present system at the study area, the method of washing root vegetables are by trampling under feet in running water like streams and also in washing yards. This not only damages the product but also results in contamination because it is constantly rubbed with the feet. The operation requires more labour and the labourers are constantly exposed to chill water during the washing operation. There is no primary processing equipment like washers for these root crops adopted by farmers in this region. The primary motive of this study was to develop a small capacity root vegetable washer suitable for small farmers with improved quality, time and labour savings.

**MATERIALS AND METHODS**

Freshly harvested carrot and raddish of local cultivars were used for the study.

**Physical properties of carrot and raddish**

The physical and frictional properties of the root crops such as carrot and raddish were studied to arrive at the design parameters of the washer. The experiments were repeated five times on individual samples to minimize the error. The various physical properties like size, volume, specific gravity and frictional properties were determined for carrot and raddish. The local variety of carrot purchased from the market and white variety of raddish were used for the study. The length and breadth were measured with a digital vernier caliper of least count of 0.01 mm. Volume was determined by water displacement procedure and the surface area by plotting in a graph (Mohsenin, 1986).

The static and dynamic coefficient of friction for carrot and raddish were determined with respect to two different surfaces such as mild steel and stainless steel. An apparatus consisting of a frictionless pulley fitted on a frame, a topless and bottomless box, loading and pan and test surfaces was used for measuring the frictional properties of the selected root vegetables. The box is connected to the loading pan by means of a string. The string is drawn parallel to the surface of the material to be tested passed over the frictionless pulley and suspended from the pulley for easy loading.

**Development of manually operated vegetable washer**

The vegetable washer being manually operated, the washer was designed and developed based on the anthropometric data for agricultural workers of Tamil Nadu (Kathirvel et al., 2006) for easy operation of the washer. The height of the drum was fixed at 95 cm from ground level. The elbow height was fixed at 80 cm for easy rotation of hand wheel. The washer drum being cylindrical, the height of the drum was found to be 45 cm for holding 10 kg of the produce. The mat type washer consists of a stainless steel drum of 47 cm length and 39 cm diameter. One third of the drum is provided with perforated holes of 0.65 mm diameter. Two third of the surface area is being provided with matting. Trials were conducted with 5 mm thickness (food grade) rubber matting with bubble like projections and also with plastic matting of 1.5 and 3.5 mm thicknesses. The centre shaft is provided with fine holes for spraying water. The pipe is connected with a coupling to a hose through which water could be sprayed to the drum. The detopping unit is mounted at 30 cm distance from the drum. A platform of size 24 × 24 cm is provided for keeping the vegetables and detopped vegetables are fed into the washing drum through a chute of 21 cm length and at a slope of 84°. Detopping is carried with the aid of a knife fitted along the side of the loading platform. For easy rotation of the drum, a step up gear of 1:4 speed ratio has been provided. The unit could be rotated with the help of hand wheel.

**Performance parameters of vegetable washer**

The performance of the developed washer was evaluated based on the washing efficiency, cleaning efficiency and bruise index as per the procedure mentioned below:

Washing efficiency = \[ \frac{\text{Weight of tubers after washing}}{\text{Weight of tubers before washing}} \times 100 \]

Cleaning efficiency = \[ \frac{\text{No. of cleaned tubers free of fibers}}{\text{Total no. of tubers}} \times 100 \]

Bruise Index = 0.5 (scrapings) + 1 (S1) + 1.5 (S2) + 3 (M) + 8(SEV) +2T

Where, Scraping = surface abrasion (no depth); S1 = 0 to 5 mm depth; S2 = 5.1 to 10 mm depth; M = 10.1 to 20 mm depth; SEV = >20 mm depth, and T = a broken tip 25 mm diameter or larger.

A two factor completely randomized block design was followed to find the effect of different matting on cleaning, washing efficiencies and bruise index on washing of carrot and raddish samples. Each experiment was replicated thrice.

**Field trials on the developed vegetable washer**

Improved carrot quality, reduction in time and labour were the primary benefits of the mechanical carrot washer compared with the manual washing system. About 10 kg of freshly harvested carrots and raddish under separate trials were analysed for cooking in the mat type vegetable washer, with different mattings, that is, rubber matting of 5 mm thickness, plastic matting of 1.5 and 3.5 mm thickness, respectively (Figure 1).
RESULTS AND DISCUSSION

Gravimetric and frictional properties of carrot and raddish

The physical properties of carrot and raddish are presented in Table 1. The average length of carrots and raddish was 1215 and 1412 mm, respectively. Similarly the breadth of the tubers at top, middle and bottom portions were measured and it was found that the breadth was more at the top for both carrot and raddish than at the bottom. This may be due to the conical shape of the tubers. The average volume for carrot was 70000 mm$^3$ and that for raddish was 121000 mm$^3$, respectively. Similar study for potatoes was carried by Negar et al. (2012). The surface area for carrots was of 1750 mm$^2$.
Table 1. Physical properties of the selected root vegetables.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Vegetable</th>
<th>Length (mm)</th>
<th>Breadth (mm)</th>
<th>Volume (mm³)</th>
<th>Surface area (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Top</td>
<td>Middle</td>
<td>Bottom</td>
<td>Top</td>
</tr>
<tr>
<td>1</td>
<td>Carrot</td>
<td>1215±22.5</td>
<td>317±13.2</td>
<td>250±14.8</td>
<td>212±13.5</td>
</tr>
<tr>
<td>2</td>
<td>Raddish</td>
<td>1412±37.6</td>
<td>298±16.8</td>
<td>252±13.6</td>
<td>224±10.5</td>
</tr>
</tbody>
</table>

Table 2. Frictional properties of the selected root vegetables.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Vegetable</th>
<th>Material</th>
<th>Coefficient of friction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Static</td>
</tr>
<tr>
<td>1</td>
<td>Carrot</td>
<td>MS</td>
<td>0.7±0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SS</td>
<td>0.6±0.01</td>
</tr>
<tr>
<td>2</td>
<td>Raddish</td>
<td>MS</td>
<td>0.63±0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SS</td>
<td>0.37±0.03</td>
</tr>
</tbody>
</table>

and that of raddish was 2450 mm². Material and surface type have considerable effects on the coefficient of friction.

The results of static coefficient of friction and dynamic coefficient of friction over the different surfaces like mild steel and stainless steel revealed that among the different surfaces, mild steel surface showed higher frictional values under static and dynamic conditions, when compared to the stainless steel surface for both carrot and raddish samples (Table 2). The static coefficient of friction over mild steel (MS) surface for carrot was 0.7 and that for stainless steel (SS) it was 0.6. Similarly for raddish, the static coefficient of friction over mild steel was 0.63 and over stainless steel was 0.37. The dynamic coefficient of friction was 0.62 and 0.54 over mild and stainless steel for carrot and 0.6 and 0.36 for raddish, respectively. The coefficient of friction (static and dynamic) was lesser in the case of raddish compared to carrot. This may be due to the larger size of the tubers.

Similar study was conducted by Razavi and Milani (2006) for water melon seeds, where the static coefficient of friction varied from 0.26 on glass and 0.626 on rubber surface.

**Effect of matting surfaces on the performance of vegetable washer**

Data on performance of root vegetable washer indicated that the different matting surfaces affected the cleaning, washing parameters as shown in Table 3. In the case of rubber matting of 5 mm thickness, the washing efficiency was found to be good for both carrot and raddish. It was found that higher cleaning efficiency could be achieved, that is, removal of fibrous roots for both carrot and raddish in mat type washer. However, the bruise index was found to be at the higher side due to the severe bruises observed at the top and tail end of the tubers. This may be due to the bubble like projections in the mat which results in a rough surface. Jayashree and Viswanathan (2010) reported that the bruise index increased with increase in operating drum speed for washing of ginger rhizomes. Though the washing and cleaning efficiency was good using rubber matting, due to the higher bruise index which indicates damage to the tubers, another set of experiments were conducted with plastic matting. In the case of plastic matting, washing efficiency was more for carrot and raddish at 3.5 mm thickness compared to 1.5 mm thickness for the same produce. The cleaning efficiency was also more in the case of 3.5 mm thickness for carrot and raddish respectively than at 1.5 mm thickness. In the case of 1.5 mm thickness plastic matting, the washing efficiency was
Table 3. Evaluation of vegetable washer with different matting surfaces.

<table>
<thead>
<tr>
<th>Type of matting</th>
<th>Vegetables</th>
<th>Washing efficiency (%)</th>
<th>Cleaning efficiency (%)</th>
<th>Bruise Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubber, 5 mm thickness</td>
<td>Carrot</td>
<td>95±0.70 (^{c})</td>
<td>90±0.94 (^{c})</td>
<td>30.5±0.82 (^{c})</td>
</tr>
<tr>
<td></td>
<td>Raddish</td>
<td>96±0.47 (^{c})</td>
<td>87±0.69 (^{c})</td>
<td>32.0±0.71 (^{c})</td>
</tr>
<tr>
<td>Plastic, 1.5 mm thickness</td>
<td>Carrot</td>
<td>95±0.71 (^{b})</td>
<td>88±0.70 (^{b})</td>
<td>1.5±0.05 (^{b})</td>
</tr>
<tr>
<td></td>
<td>Raddish</td>
<td>95±0.51 (^{b})</td>
<td>85±0.74 (^{b})</td>
<td>6.1±0.16 (^{b})</td>
</tr>
<tr>
<td>Plastic, 3.5 mm thickness</td>
<td>Carrot</td>
<td>97±0.47 (^{a})</td>
<td>91±0.70 (^{a})</td>
<td>1.25±0.10 (^{a})</td>
</tr>
<tr>
<td></td>
<td>Raddish</td>
<td>96±0.94 (^{a})</td>
<td>90±0.94 (^{a})</td>
<td>6.05±0.13 (^{a})</td>
</tr>
<tr>
<td>C.V</td>
<td></td>
<td>1.86%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

v, Vegetables; m, matting surface.

found to be on par for both carrot and raddish. The cleaning efficiency was found to be 88% for carrot and 85% for raddish. The bruise index was less in the case of carrot at 3.5 mm thickness compared to raddish at the same thickness of matting.

Statistical analysis revealed that there was a significant difference on the performance parameters among the different matting surfaces. The plastic matting of 3.5 mm thickness was good in performance in terms of washing and cleaning of the tubers with low bruise index.

Conclusion

The developed manually operated root vegetable washer was of 10 kg holding capacity and it was found suitable for washing root crops like carrot and raddish. The washer was evaluated in the farmer’s field. Performance trials revealed that 3.5 mm plastic matting gave better performance in terms of washing and cleaning efficiencies of 97 and 91% for carrot and 96 and 90% for raddish, respectively with lesser bruise index.

REFERENCES