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Development and Performance Evaluation of a Continuous Type Root Vegetable Washer

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A continuous type root vegetable washer was developed for washing crops like carrot and radish. The equipment consists of a HDPE washing drum, spray assembly, chassis and drive mechanism. The performance of the washer was assessed in terms of washing efficiency, cleaning efficiency and bruise index. The vegetable washer which was continuous in operation was tested for washing carrot in farmers fields. The washing efficiency and cleaning efficiency were found to be 88 % and 91 % for carrot respectively. The damage to the tubers while washing was found to be negligible. The capacity of the equipment was found to be 350 kg/h for carrot with a savings in labour about 70 per cent.

Key words: root crops, mechanical washer, washing efficiency, cleaning efficiency, bruise index

Root crops like carrot, radish, grow in heavy soils and are grown by small farmers. As the vegetable tubers grow under the soil, lot of mud and dirt adhere to them. They are manually harvested with leaves to minimize damage while handling and making them vulnerable to contamination due to microbial actions, physical damage, bruising etc. It is necessary to wash off the mud and soil particles in the field itself as a primary processing operation to improve the physical appeal and also to aid in further processing. Washing and sanitizing treatment can play an important role in reducing microbial population on fresh fruits and vegetables intended for fresh market or fresh- -cut processing, thereby improving product quality and safety (Sapers, 2001).

In the hilly regions like Udhagamandalam, Tamil Nadu, the conventional method of washing root vegetables are by unhygienic way of trampling under feet in running water like streams and also in washing yard. 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. Various other methods used for washing away the soil and mud are immersing the produce in tank full of water, spraying with water, agitating with water, rubbing with brushes in water tank water jet washing and immersion/ soaking methods which employ more persons and the efficiency of mud removal is lesser. The primary motivations for development of mechanical washer are improved quality, time and labor savings, and improved speed and efficiency of handling.

Materials and Methods

Development of washer

The major components of the prototype washer were a barrel, spray assembly, chassis and drive mechanism. The developed washer was a movable unit and hence easy to transport to the washing location.

The washing drum was a HDPE drum of 580 mm diameter and 880 mm long with a wall thickness of 6 mm. The drum was perforated with 12 mm diameter holes for drainage. The drum was mounted on two metallic rollers. Hence the drum could be easily tilted or removed for cleaning. Inside the drum, plastic matting of 3.5 mm thickness was provided throughout it's circumference for removal of fibrous roots from the tubers. A set of brushes could be added to the tumbler bars for improved cleaning action. (Moos, 2002)

Eight numbers of tumbler bars of size 300x25x15 were fitted inside the washing drum at a spacing of 240 mm from the centre. This facilitated easy mixing and to ensure that the water spray contacts the entire tuber surfaces. Feeding of the fresh produce was through one end and collection through the other end of the washing drum. The spray wand assembly consisted of a centre stainless steel pipe of 1470 mm length provided with 2 mm diameter holes at a spacing of 25 mm for spraying water inside the drum. The pipe was connected to the hose through a coupling. The chassis and drive mechanism consisted of two metal rollers mounted on a frame. One of the rollers was power driven and the other roller was an idle one. The running roller was driven by one hp single phase electric motor through a V belt. (Fig.1)

Performance of vegetable washer

The developed vegetable washer was evaluated in farmers' fields for its performance. Freshly harvested carrot were detopped and fed into the rotary drum rotating at 10 rpm for washing and cleaning of the tubers. The performance of the developed washer

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was evaluated based on the washing efficiency, cleaning efficiency and bruise index as per the procedure mentioned below:

Washing of the vegetables indicated as washing efficiency was determined based on the reduction in weight of the crops after removing of adhering soil and dirt.

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

Cleaning efficiency is the removal of fibrous roots from the tubers. In a sample lot, the number of cleaned tubers free of fibers refers to the extent of cleaning.

$$\text{Cleaning efficiency} = \frac{\text{No. of Cleaned tubers free of fibers}}{\text{Total No of tubers}} \times 100$$

Bruise Index is a measure of extent of damage to the tubers while cleaning and a visual damage grading technique. A sample of the tubers from the lot was graded for assessing the number of surface injuries. The injuries were classified based on severity of damage such as scrapings, cracks, cuts and breakages multiplied by a scaling factor. (Moden and Peterson, 1989)

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

T= a broken tip 25 mm diameter or larger

Laboratory trials for optimisation of cleaning parameters

An experimental prototype was fabricated and tested for carrots under laboratory conditions, to optimize the cleaning parameters like the bristle thickness and speed of rotation. By initial trials, bristles from medium soft to medium hardness range (0.5 to 0.7 mm) and the speed of rotation of the drum as 25, 50, 75 and 100 rpm were selected considering the ease of operation and also for effective cleaning without bruises. Slower speeds tended to make it difficult for the unit to start and keep rotating, while faster speeds were not used to avoid carrot breakage (Moos *et al.,* 2002)

The optimum bristle thickness was selected by washing carrots under laboratory condition. Carrots were procured from the market and were simulated to the harvested condition by smearing with a mud paste and partially drying it according to the standard procedure.

Field evaluation of washer

The developed prototype washer with optimized machine parameters at laboratory condition was evaluated for washing of freshly harvested raddish and carrot at farmers end. The performance in terms of washing and cleaning efficiencies were recorded. (Fig. 4)

Statistical Analysis

The results on the effect of washing speed and bristle thickness on cleaning was statistically analysed as per two way ANOVA using computer software package AgRes. Each experiment was replicated thrice.

Results and Discussion

Effect of drum speed and bristle thickness on washing carrot:

In the laboratory level experiments, there was no damage to the tubers while washing at different bristle thickness at lower speed viz. 25, 50 & 75 rpm. The effect of washing time and speed were significant in the mechanical washing of turmeric (Arora *et al.,* 2007) The washing efficiency was found to be 97 %

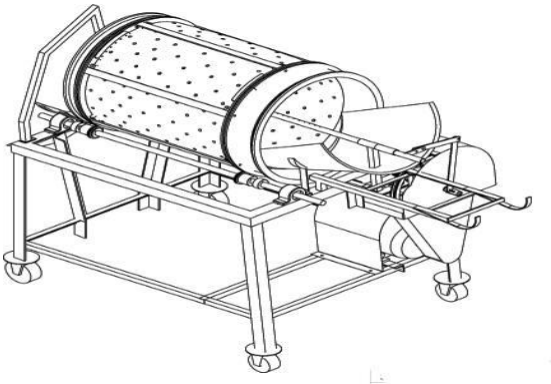

Fig. 1. Continuous type root vegetable washer

at a bristle thickness of 0.7 mm at higher speed of rotation i.e. 75 & 100 rpm respectively (Fig 2). In the case of number of washings, it was found that at 50, 75 and 100 rpm for a bristle thickness of 0.7 mm, carrots required only one wash compared to the other bristle thickness. (Fig. 3) More number of washings will result in time consumption, labour adding to the cost of operation. The washing efficiency was found to be on par at 100 rpm and 75 rpm speed for the same bristle thickness of 0.7 mm.

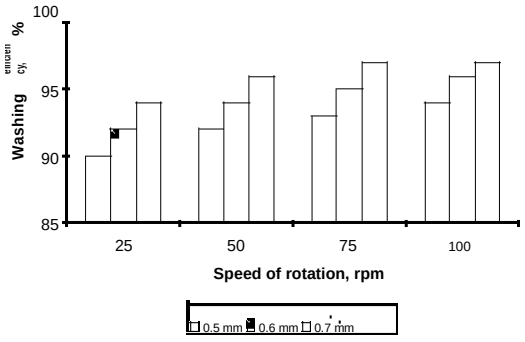

Fig. 2. Washing efficiency at different bristle thickness and speed

Table 1. Washing efficiency for carrot under laboratory condition

Drumspeed, rpm (r)	Bristle thickness, mm (t)	Washing efficiency, %	
25	0.5	90	
50		92	
75		94	
100		94	
25	0.6	92	
50		94	
75		96	
100		97	
25	0.7	93	
50		95	
75		97	
100		97	
		SED	CD (0.05)
	r	0.15	0.31
	t	0.17	0.36
	r x t	0.30	0.62

At 100 rpm the percentage damage was found to be 3-5 per cent for different bristle thickness. Hence the maximum speed of rotation was limited to 75 rpm without any damage to the product.

Table 2. Field Evaluation of vegetable washer

Product	Washing efficiency, %	Cleaning efficiency,%	Bruise Index
Carrot	91±0.57	88±0.74	1.5±0.05

The washing efficiency of carrot at different speed of rotation and bristle thickness were statistically analyzed, the results of which are presented in table 1. There was significant difference among the different treatments. The washing efficiency was found to be higher at r3 (75 rpm) and r4 (100 rpm) compared to other speeds. However washing at 100 rpm speed resulted in damage to the tubers and hence the maximum speed was limited to 75 rpm. Moos *et al.,* (2002) reported that faster speeds were not recommended to avoid produce damage. r1 (25rpm) was the poorest among the treatments.

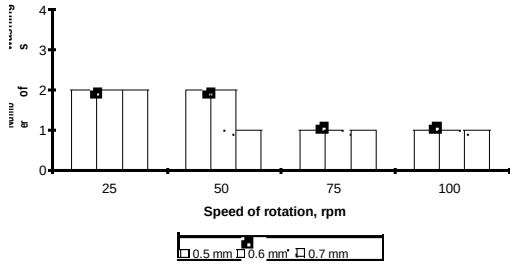

Fig. 3. Number of washings at different bristle thickness and speed

Fig. 4. Continuous type root vegetable washer in operation

In the case of bristle thickness, t3 (0.7 mm) gave the best performance and t1 (0.5 mm) gave poor results. Hence it was found that 0.7 mm bristle thickness was ideal for washing of carrots.

Performance evaluation of continuous type vegetable washer

The prototype vegetable washer which was continuous in operation was tested for washing carrot at the village Jantha Medu, Udhagamandalam, Tamil Nadu. The washing efficiency was 91 per cent and the cleaning efficiency was 88 per cent, with negligible damage to tubers. Jayashree and Viswanathan, (2010) reported washing efficiency of 97.8 per cent with a bruise index of 7.5 could be achieved for mechanical washing of ginger rhizomes. The capacity of the equipment was found to be 350 kg/h. (Table 2)

Cost economics of machine washing

It was found that washing in the continuous type washer, the cost for washing one kg of carrot works out to be Rs.0.2/ whereas the manual washing costs Rs.1.25/ kg. Thereby 84 per cent in the cost of washing 70 per cent in labour could be saved.

The optimum bristle thickness for effective cleaning was found to be 0.7mm under laboratory condition. The developed vegetable washer was found suitable for the small farmers based on its performance with 91 per cent washing efficiency and 88 per cent cleaning efficiency for carrots.

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