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Design, Development and Evaluation of Portable Washer for Lotus Rhizomes

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The aim of the present study was to design, develop and evaluate a low cost portable washer for Lotus Rhizomes. Different performance parameters and colour values were studied to check the performance of the developed prototype in comparison to the manual washing. The capacity and efficiency of the machine was much higher than the existing manual method of washing. The colour coordinates (L* a* b*) revealed that washing through developed washer makes lotus rhizomes more clean and bright as compared to the manual washing. Different sanitizers were also tested for shelf life enhancement of lotus rhizomes. Out of all tested sanitizers, the citric acid was found best with regard to shelf life enhancement and cleanliness of lotus rhizomes. The economic analysis reveals that the developed lotus rhizome washer can be beneficial for the people who are directly or indirectly involved in lotus rhizome trade.

Keywords: Lotus rhizomes, lotus rhizome washer, throughput capacity, cleaning efficiency, colour values, sanitizers, cost analysis

Introduction

In India, lotus plant flourishes in almost all the lakes and water bodies[1].The edible part of the lotus plant is its root (rhizome). There is a lot of dirt inside the lotus rhizomes, which is difficult to clean through simple washing. The manual washing/cleaning does not remove dirt and mud properly from inside the lotus rhizomes which reduces their shelf life and commercial value. Therefore, present study was conducted in order to overcome drudgery, boredom and other constraints associated with manual washing of lotus rhizomes.

Materials and methods

Design and development of lotus rhizome washer

A low cost portable washer for lotus rhizomes was designed and developed at Division of Agricultural Engineering and Food Science and Technology, SKUAST-K, India during the year 2017-18. Through AutoCAD software, drawing model (Figure1a and 1b) was developed for the prototype to suffice the design considerations. The washer consists of main frame, reservoir/ Tank, pressure control valve, outlet pipe/suction and delivery pipe, washing probe, Pressure gun, motor, tee joints and control box (Figure1a and 1b). The details about material of construction and dimensions of different components of the machine are depicted in Table 1.

Working operation

High pressure water aids in cleaning of lotus rhizomes. Water enters through suction pipe into the pump and comes out through washing probe with high pressure. The highpressure water hits the inner surface of lotus rhizomes and removes the dust, dirt, mud and other adhered materials inside the lotus rhizomes. In order to ensure the proper cleaning and to prevent any physical damage to inner surface of lotus rhizomes, the pressure and discharge of water is controlled by means of gun fitted at the end of delivery pipe.

Performance evaluation

Hundred bundles of lotus rhizomes weighing about 220 kg immediately after harvesting from Dal lake Srinagar J&K, during October, 2018 were brought to Division of Food science and Technology, Sher-e-Kashmir university of Agricultural science and Technology, Kashmir, India to evaluate the developed washer. Performance parameters and color values were used as the criteria to evaluate the performance of developed prototype. Existing washing/cleaning

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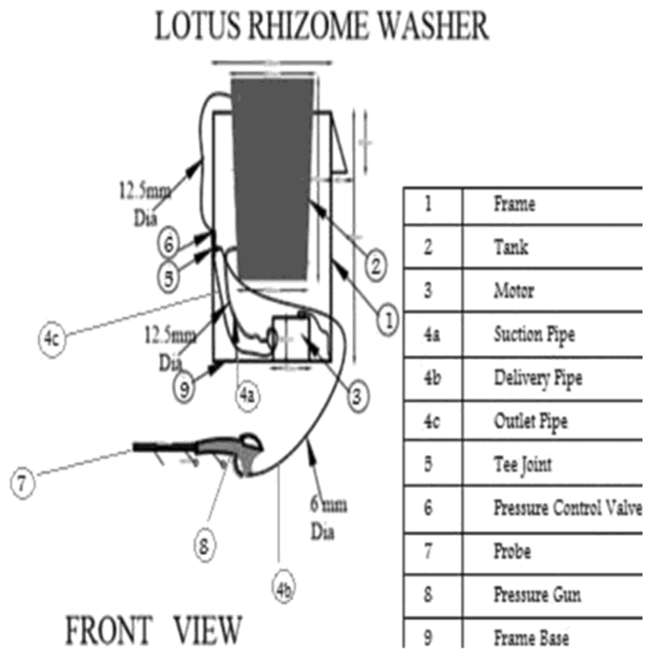

Fig. 1a — Front view of lotus washer machine

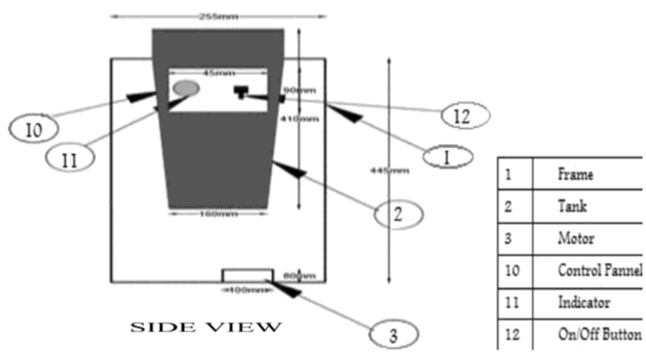

Fig.1b — Side view of lotus washer machine

practice of lotus rhizomes was also evaluated in order to compare the manual and mechanical methods of washing.

Performance parameters

The standard procedures and formulas were used for determining the performance of washer in terms of throughput capacity (%), cleaning efficiency(%) andlabor requirement (man-hr/tonne).

Color coordinates

The colour coordinates- L*(Darkest black at L*=0 and brightest white at L*=100), a*(red at positive value of a* and green at negative value of a*) and b*(yellow at positive value of b* and blue at negative value b*) of cleaned lotus rhizomes were determined using a hunter lab calorimeter (Model CM-508d Minolta co. Ltd Japan) as per the standard method.

Effect of sanitizers

In order to enhance the shelf life of Lotus Rhizome, three different types of sanitizers i.e., acetic acid, citric acid and ascorbic acid were mixed with tap water @ 4% each. The Lotus rhizomes were subjected to cleaning using all the three types of sanitizing solutions by means of developed washer. The shelf life studies and color analysis of both treated and un-treated samples were conducted during three days of storage period under ambient conditions.

Physiological loss in weight

For determining Physiological Loss in weight (PLW), weight of Lotus Rhizomes was recorded using electronic balance at periodical intervals. The PLW was computed as the difference in weight from first day to the subsequent day using the following formula:

PLW (%) = Initial weight – weight after known storage period/ initial weigh× 100 … (1)

Visual score

During storage, the samples were given visual scores on each day of known storage period on a 5-point scale as: Excellent= 5; Very good= 4; Good= 3; Fair= 2 and Poor=1.

Economic analysis

In order to determine the techno-economic feasibility of developed prototype, benefit cost ratio (BC ratio), break-even point (BEP) and pay back period were determined.

Statistical analysis

Each measurement was replicated five times and data obtained was analyzed using SPSS Software (SPSS PASW 18.0) and means were separated using Duncan multiple test ($p \leq .05$).

Result & Discussion

Comparative evaluation of manual and mechanical washing

The lotus rhizomes were subjected to cleaning by developed washer as well as by existing manual method of cleaning. The results shown in Table 2 depict that throughput capacity, efficiency (%), labour requirement (man-hr/tonne) and L*, a*, b* colour coordinates were significantly different ($p<0.05$) in both manual and mechanical washing.Throughput capacity of the developed washer was recorded as 7.13kg/hr which was significantly ($p<0.05$) higher than the manual capacity of 4.05kg/hr (Table 2).

Previously, many researchers have reported higher throughput capacity during mechanical operation than manual operations. The labor requirement involved in cleaning one tonneof Lotus rhizomes was estimated to be 247 man-hours in manual cleaning and only 140 man-hours (Table 2) in case of mechanical cleaning. Due to high throughput capacity of machine the labor requirement was less in mechanical washing than manual washing. Besides the efficiency of the developed prototype was estimated to be 95.10% which was significantly higher ($p<0.05$) than the efficiency of 78.85% recorded in case of manual washing. Various similar studies have also reported higher efficiencies in mechanical operations than manual methods in different unit operations[2, 3]. Both manually and mechanically washed lotus rhizomes were subjected to colour analysis using hunter lab calorimeter. The L*, a* and b* values of lotus rhizomes subjected to manual and mechanical washing were found to be significantly different ($p<0.05$). The L* value of mechanically washed lotus rhizomes was found significantly higher (65.34) than the manually washed rhizomes (56.22) (Table 2). L* value represents darkest black at L* =0 and brightest white at L* = 100. The highest L* value in case of mechanically washed rhizomes, therefore indicate that mechanically washed samples were brighter and clean than the manually washed samples. The negative a* value indicates the greenness in the samples. The a* value of manually washed lotus rhizomes was more towards negative side (-1.52), than the mechanically washed rhizomes (-1.33) (Table 2), which indicate that manually washed rhizomes were less cleaned than mechanically washed rhizomes. b* value was found in positive range for both manually and mechanically washed lotus rhizomes. The higher b* value of manually washed rhizomes (24.79) than mechanically washedones (23.74), indicate that manually washed rhizomes were more yellowish in colour than mechanically washed rhizomes. Similar results have been reported for color coordinates in various studies conducted on vegetable washing[4].

Effect of sanitizers on physiological loss in weight, colour values and visual colour score

The different sanitizing solutions were tested for cleaning of lotus rhizomes using developed washer. The results obtained are depicted in Table 3.

Table1 — Material of construction and dimensional details

S. No	Components	Material Used	Dimensional Details
1	Main frame	Galvanized iron, Hollow square pipes	Length× Breadth × Height 325mm×250mm×455mm Size of square pipe =25 × 25mm
2	Reservoir (Tank)	Plastic (PVC)	370mm×190mm×350mm Capacity= 17litres Thickness=2.2mm
3	Motor	0.05 kW (single phase)	RPM=1440
4	Suction &Outlet pipe	Plastic (PVC)	Diameter=12.5mm
5	Delivery pipe	Plastic (PVC)	Diameter = 8mm
6	Pressure control valve	Plastic (PVC)	Diameter=25mm Thickness=4mm
7	Washing Probe	Stainless steel	Length ×diameter =225 mm×2mm
8	Pressure Gun	Handle=Plastic(PVC) Nozzle=Stainless steel	Inner diameter=25mm
9	Control Box	MS sheet	205mm× 100mm

Table 2 — Comparative evaluation of manual and mechanical washing of lotus rhizomes

Parameters		Manual washing	Mechanical washing using developed washer	CD at 5%
Throughput Capacity (kg/hr)		4.05kg/hr/person	7.13kg/hr	1.5
Efficiency (%)		78.85	95.10	2.85
Labour requirement (man-hr/t)		247	140	3.60
Colour coordinates	L*	56.22	65.34	0.60
	a*	-1.52	-1.33	0.10
	b*	24.79	23.74	0.85

Table 3 Effect of sanitizers on physiological loss in weight (PLW), colour coordinates and visual colour score of lotus rhizomes

Washing solutions used	PLW (%)				L*				a*				b*				Visual colour score			
	End of day I	End of day II	End of day III	Mean	End of day I	End of day II	End of day III	Mean	End of day I	End of day II	End of day III	Mean	End of day I	End of day II	End of day III	Mean	End of day I	End of day II	End of day III	Mean
Control*	7.28	20.74	35.00	**21.00**	50.15	37.71	19.65	**35.83**	-1.64	-1.72	-1.84	**-1.73**	25.54	28.94	31.86	**28.78**	2.5	1.5	UA** (0.22)***	**1.59**
Tap water	5.92	13.91	22.54	**14.12**	65.34	52.76	31.41	**49.74**	-1.33	-1.42	-1.59	**-1.45**	23.74	26.40	28.76	**26.30**	4.5	4.0	2.0	**2.83**
Acetic acid (4% conc.)	5.76	13.61	18.85	**12.74**	68.20	59.03	49.62	**58.95**	-1.25	-1.37	-1.51	**-1.37**	20.26	23.09	25.32	**22.89**	4.5	4.0	2.5	**3.66**
Citric acid (4% conc.)	4.42	9.18	12.24	**8.61**	72.26	68.13	59.93	**66.77**	-1.15	-1.26	-1.43	**-1.28**	16.78	18.06	20.31	**18.38**	5.0	4.5	4.0	**4.50**
Ascorbic acid (4% conc.)	5.25	10.45	14.29	**9.98**	70.42	61.84	53.61	**61.95**	-1.20	-1.30	-1.48	**-1.38**	18.22	21.13	22.41	**20.59**	4.5	4.0	3.5	**4.00**
Mean	**5.78**	**13.31**	**20.80**		**64.39**	**56.57**	**42.65**		**-1.31**	**1.41**	**1.57**		**20.42**	**23.60**	**25.44**		**4.5**	**3.6**	**2.43**	
CD at 5% (Treatment)	**1.86**				**1.15**				**0.031**				**2.40**				**1.44**			
CD at 5% (Storage)	**1.90**				**1.63**				**0.021**				**2.89**				**2.30**			

*Control indicates un-washed lotus rhizomes
**UA = Unacceptable
***is transformed value for statistical analysis

Physiological loss in weight (PLW)

PLW is one of the important parameter to decide the shelf life, even if the commodity is free from physical and microbial abuse. It is very difficult to control PLW under normal post-harvest conditions. Fruits and vegetables are considered to be good if PLW is in the range of 5-10%.Usually, after 10% of PLW, fruits and vegetables become shrink and loses the organoleptic qualities. In the present study, PLW of both treated as well as untreated samples increased significantly ($p<0.05$) with the advancement of storage period. The increase was however, slows in the beginning and more as the storage period advanced. The lowest PLW was recorded at the end of first day of storage irrespective of the washing solution used. Out of different tested sanitizers, citric acid proved to be the most effective with PLW percentages of 4.42, 9.18 and 12.24 at the end of day I, day II and day III respectively (Table 3). The physiological loss in weight is mainly due to respiration and transpiration losses occurring during the metabolic processes and also by atmospheric storage conditions in terms of low relative humidity which triggers the pressure difference between the commodity and the surrounding storage conditions. Increase in PLW towards the end of storage in the present study is perhaps due to water movement from inside of lotus rhizomes to surface, release of volatiles containing ethylene, CO_2 and water vapour by respiration and also evaporation of water from surface of rhizomes during storage. However, percent increase in PLW was more pronounced in case of control (Table 3) due to high rate of transpiration and respiration. The data given in Table 3 reveals that out of different sanitizers used the lowest PLW% during storage was recorded in lotus rhizomes washed with citric acid (4%) followed by ascorbic acid washing (4%) and acetic acid washing (4%). The lowest reduction in weight loss of citric acid treated rhizomes may be attributed to low levels of respiration and transpiration losses in such samples. Further, the degree of dissociation for a particular acid is related to its dissociation constant and the acidity of the product. Citric acid having high pKa (4.8) has higher antibacterial effect than acetic acid and ascorbic acid. Similar findings have been reported in previous vegetable washing studies as well.[5]

Colour coordinates

The colour coordinates of lotus rhizomes treated with different sanitizers were found to be significantly different ($p<0.05$) during the storage period. The L* values of both treated as well as control samples were decreased significantly ($p<0.05$) during the storage period for 3 days. Out of different tested sanitizing solutions, the highest decrease in L* value was noted in acetic acid washed samples followed by ascorbic acid and citric acid (Table 3). Conversely, the a* and b* values increased significantly ($p<0.05$) in both treated as well as in control samples during storage. At the end of first day of storage, the lowest L* value (50.15) was recorded in control, which was reflected in their highest a* (-1.64) and b* (25.54) values as well (Table 3). Out of different tested sanitizing solutions, the rhizomes washed with citric acid were found brighter (with highest L* value 72.26) and less reddish and yellowish (with least a* value -1.15 and 16.78 b* value) followed by ascorbic acid treated rhizomes and acetic acid treated rhizomes at the end of first day of storage. Similar trend was recorded during the second and third day of storage as well. Since citric acid is strong acid than acetic acid and ascorbic acid, it therefore reduces the pH value and thus inactivates the activity of polyphenol oxidase which reduces the chances of browning during storage.

Visual colour score

During the storage period, visual colour score was found to decrease significantly ($p<0.05$) in both control as well as in treated samples. At the end of first day of storage, highest visual colour score of 5 was recorded for citric acid treated rhizomes and least score of 2.5 in case of control. On third day of storage, the highest colour score was again observed in case of citric acid treated rhizomes (4.0) followed by ascorbic acid treated rhizomes (3.5) and acetic acid treated rhizomes (2.5) (Table 3). The colour score recorded in case of rhizomes washed with tap water on third day of storage was only 2.0 whereas the control sample was unacceptable on third day of storage (Table 3). Therefore, findings are in concomitance with the findings reported in a similar type of study conducted on fruits and vegetables.

Economic analysis of developed low cost portable washer

The analysis of various economic parameters i.e. benefit cost ratio, breakeven point and payback period revealed that by using developed prototype all the economic parameters can be optimally achieved and the cost of washing can be reduced compared to traditional method of washing. B:C ratio of 1.33 obtained for mechanical washing reveals that the developed prototype is highly beneficial and economical. Break-even point of 619.87 kg was recorded for developed prototype. It is therefore recommended that the people involved in its trade can successfully use the developed prototype for washing of Lotus Rhizomes on commercial scale. The payback period for developed prototype was estimated to be 5.38 months which indicates that the initial investment (Rs 6000) involved in procurement of developed washer can be regained only in a period of 5.38 months. Therefore, investment on developed prototype can be a successful venture for the people involved in lotus rhizome trade. Hence, it is concluded from economic analysis that the developed Lotus Rhizome washer is cheap, economically viable and suitable for washing of lotus rhizomes.

Conclusion

In Kashmir, Lotus Rhizomes after harvesting are washed manually using knitting needles or broom sticks, which is very time consuming, troublesome and a tedious practice. The inner sides of lotus rhizome washed in this fashion have stained spots and un-attractive appearance, which reduces their shelf life as well as commercial value. Therefore, a power driven Lotus Rhizome washer having a capacity of 7.13kg/hr and efficiency of 95.10% was designed and developed. Based on the cleaning efficiency, throughput capacity and economic analysis it was concluded that the developed prototype is cheap, economically viable and suitable for washing all sizes of Lotus Rhizomes of Kashmir. Furthermore, out of different sanitizers tested, citric acid (4%) was found best in enhancing the shelf life of Lotus Rhizomes up to three days.

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