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Development of fresh galangal washing machine using pressurized water spray

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Abstract

The purpose of this research was to design and perform an evaluation of the galangal washing machine using pressurized water spray at water flow rates of 10, 20, and 30 l/min and speeds of 30, 50, and 70 rpm. The result of this research comparing washing the galangal by farmers and a machine found that the operating capacity was 33.22 and 122.5 kg/h, the washing efficiency was 90.95% and 35.78%, and the percentage of damage was 0.08% and 1.09%, respectively. In the future, improvements should be made to increase the washing efficiency of galangal by increasing the washing time, and a water circulation system should be added to reduce water waste.

Keywords: Washing machine, Galangal, Agricultural machinery performance

1. Introduction

Alpinia galanga (L.) Willd. is a perennial herb in the Zingiberaceae family, along with ginger, turmeric, and ginger root. Often referred to as galangal or greater galangal, it is a perennial herb native to Indonesia but cultivated in many parts of Asia, with Thailand and Indonesia being the main producers and exporters. The plant has a wide range of uses, from culinary, medicinal, the food industry, and cosmetics and perfumery [1, 2]. Galangal rhizomes are harvested year-round and are commonly used in Asian cuisine due to their pungent flavor [3]. Distinctive features of Alpinia galanga that distinguish it from other galangals are the white rhizome and pulp. The pseudo stem, rising about 10 cm from the ground, is pinkish-red. Young and mature rhizomes are used in cooking to deodorize fishy odors and as an ingredient in curry pastes. The rhizomes and young shoots are peeled and boiled as a medicinal vegetable. Mature galangal is an ingredient in traditional medicine. Extraction of essential oils for use in massage oil products [2].

Red-eyed galangal is a potential economic crop for both domestic consumption and export, particularly in Malaysia, Japan, China, and Korea. Export value is increasing annually. In 2024, Thailand had galangal planting areas of 14,078 rai, producing a total of 24,514 tons. The average selling price was 33.27 baht/kg, representing a value of over 815 million baht [4].

The seasoning manufacturing business is part of the food industry. In 2024, revenue from domestic sales accounted for approximately 56% and exports for approximately 44%. During 2025-26, revenue from the seasoning manufacturing business is expected to continue to increase, driven by domestic sales, household demand, and the growth of the ready-to-eat food and restaurant industries. Exports are also expected to expand, driven by the growth of Thai restaurants abroad. The "Thai Kitchen to the World" policy is also driving the popularity of Thai seasonings in international markets [5]. This has resulted in increased market demand for vegetables used in curry pastes, particularly galangal, which is popularly used in curry pastes for export both domestically and internationally. There are many varieties of galangal, but the red-eyed variety is more sought after in the condiment industry than any other variety due to its distinctive aroma, color, and flavor, as well as its numerous medicinal properties. Currently, farmers are widely cultivating the red-eyed variety to supply processing plants for condiment production.

There are two main ways for Thai farmers to sell galangal: Galangal that is unwashed or decontaminated is priced at 15 baht/kg, which is lower than the cleaned variety, which is priced at 30-35 baht/kg. Therefore, farmers prefer to sell cleaned galangal because it offers a higher selling value, 15-20 baht/kg, compared to unwashed galangal. The process extends from harvesting to packaging for sale, as shown in Figure 1.


Collection and Pre-washing


Washing


Trimmed to approximately 5 cm in stem length


Limewater Soaking


Air Drying


Packaging

Figure 1 Steps for preparing galangal after harvesting for sale

Traditional galangal washing processes still rely heavily on manual labor, requiring long washing times and high operating costs. Furthermore, modern machinery must be imported from overseas at high costs. Therefore, to reduce these problems, galangal washing machines are essential for farmers.

Khantho et al. [6] developed a prototype galangal washing machine costing approximately 100,000 baht, capable of processing large quantities. It uses water pressure from four flat fan nozzles with a 90-degree spray angle, achieving 5-6 times the efficiency of manual washing. Two methods were tested: an automatic system with a capacity of 300 kg/h, and batch feeding with a capacity of 405.1 kg/h. The study examined the effects of water pressure and rotational speed on performance.

Phimpha et al. [7] created a sweet potato washer with human involvement, achieving a throughput of 7.6 tons/day—four times higher than manual cleaning (1.9 tons/day). Factors such as water pressure, grinding wheel speed, and operation time influenced cleaning efficiency and quality.

Poojeera and Khanthawithi [8] tested a semi-automatic galangal washer using a flat fan nozzle with a 60^{o} spray angle. The machine cleaned 5 kg of galangal in 120 s, with better efficiency than manual washing. For 300 kg of galangal, machine and manual washing took approximately 498.7 and 589.5 minutes, respectively, with work rates of 36.09 and 30.53 kg/h.

Promkesa et al. [9] evaluated a semi-automatic vertical galangal washer, finding optimal conditions at 350 rpm, 15 min wash time, 40 l of water, washing 15 kg of galangal with 92% cleanliness. It could wash up to 600 kg/day.

Srison et al. [10] designed a Jerusalem artichoke washing machine comprising a basin, washing barrel, water purifier, and pump. Operating at 27 rpm, it washed approximately 4.93 kg/h with a cleanliness rate of 57.20%, damage rate of 9.47%, and energy consumption of 6.93 kWh in about 5-10 min.

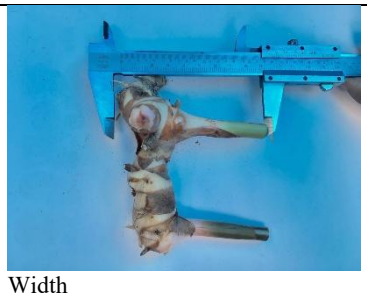
Given these important issues, this research aims to design and evaluate the performance of a fresh galangal washing machine using pressurized water spray.

2. Materials and methods

2.1 Physical properties of galangals

Fresh Galangal (*Alpinia galanga L.*) were harvested in Khon Kaen Province in the northeast of Thailand, and used as a raw material to assess this machine. The dimensions of 90 galangal were measured in trunk diameter, width, and length with Winton Vernier calipers, 1 in x 1/128 (Figure 2). The average of trunk diameter, width, and length were 1.74, 11.77, and 9.77 cm, respectively. For the washing sieve set, the average diameter and ease of accessibility in the market are considered. Therefore, a 0.5cm diameter sieve hole size was used to prevent the galangal trunk from getting stuck in the holes of the sieve while washing.


Trunk diameter


Width

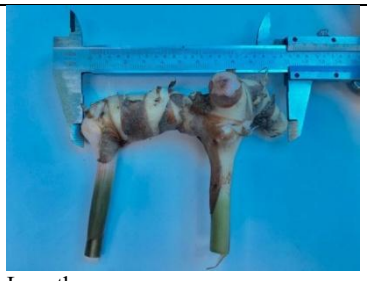

Length

Figure 2 Measuring the size of galangal

The flow angle of galangal with the steel machine surface was determined. This angle was measured 15 times using a galangal (Figure 3). An average flow angle of 30.20° is used to design the minimum angles of the feeding and the receiving tray.

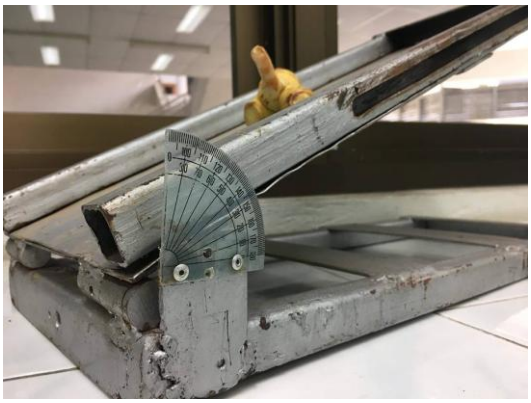


Figure 3 Testing the flow angle of galangal with the steel machine surface

2.2 Galangal washing machine by spraying pressurized water description

The galangal washing machine is designed to be ergonomically sized and portable. The machine's frame is 80 cm wide, 120 cm long, and 150 cm high. It has 8 main parts (Figure 4): 1) feeding tray, 2) washing screen set, 3) sieve hole size, 4) crescent fin, 5) receiving tray, 6) gear motor, 7) water pump, and 8) high-pressure nozzle.

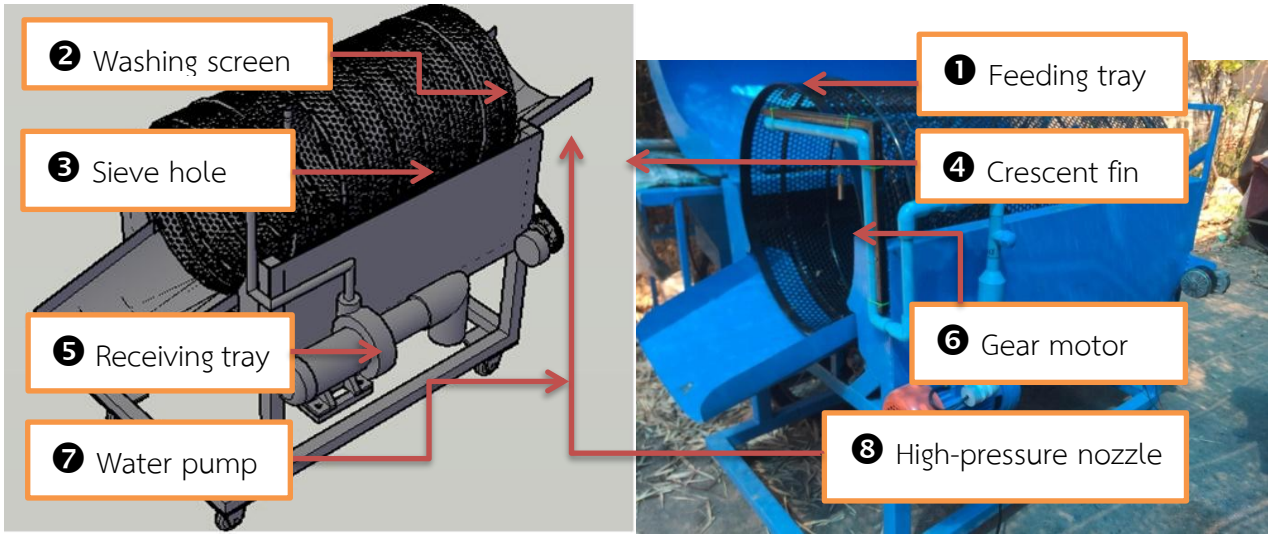


Figure 4 Galangal washing machine by spraying pressurized water

1) The feeding tray considers the convenience and can feed the galangal without any obstruction. The feeding tray tilt angle is designed at 33°. From the measurement of the average flow angle of the galangal, it is at least 30.20°.

2) The washing screen set is a cylinder with a round hole steel sieve with a diameter of 700 mm, a length of 1,200 mm, and a thickness of 1.5 mm.

3) The sieve hole size is 15 mm in diameter, designed to be smaller than the average galangal trunk diameter of 17.4 mm, to prevent galangal from getting stuck in the sieve holes.

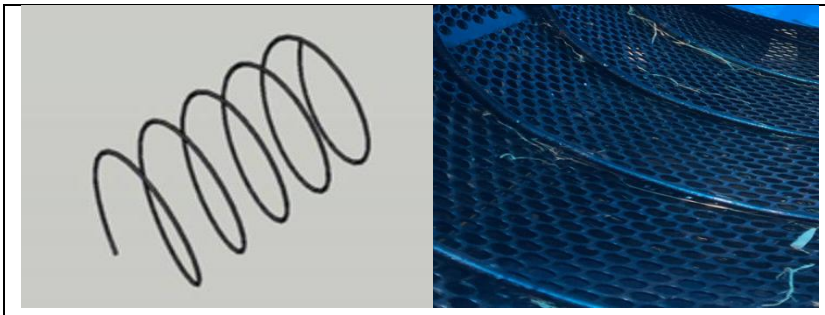
4) Crescent fin (Figure 5 (a)) for conveying galangal in and out of the washing screen set. The crescent fin is an important part that helps to improve the performance of the galangal washer; a high helix angle slows the flow of material [11]. In designing the crescent fin, have a pitch of 240 mm and a helix angle of 80°. This study used a 12 mm steel bar because it is the appropriate size for making crescent fins, does not cause material breakage, and is easily available in the market.

5) The receiving tray tilt angle is designed at 33 °, the same as the feeding tray.

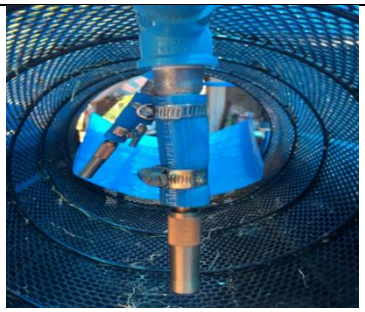
6) A gear motor 350W 24V DC (Model MY1016Z3, L-faster) is used as the power source for driving the washing grid set.

7) The water pump is an important part that will pump and send water to the nozzles. Use a centrifugal pump size 1100 W, 1.50 HP, 220 V (Model CMA 1.50 M, EBARA), suitable for the number of high-pressure nozzles, 5 heads. Before sending water through the high-pressure nozzle, use a PVC pipe class 13.5, size 12.7 mm, and control the flow rate with a ball valve.

8) The high-pressure nozzle (Figure 5 (b)), made from brass, can be adjusted in many forms. This study adjusted the full cone, even distribution type. It is corrosion-resistant and can withstand water spray pressure up to 160 bar. The washing screen set is installed with 5 nozzles with a distance between the nozzles of 15 cm to distribute water evenly.



Crescent fin



High-pressure nozzle

Figure 5 Crescent fin (a) and high-pressure nozzle (b)

2.3 Pre-testing

Pre-testing for finding the range of speed and water flow rate values to be used in the performance testing of this galangal washing machine.

1) Speed Range

The washing efficiency and damage percentage were measured at speeds of 30, 40, 50, 60, 70, 80, 90, and 100 rpm with 10 kg of galangal at a time. The graphs are shown in Figures 6 and 7, respectively.

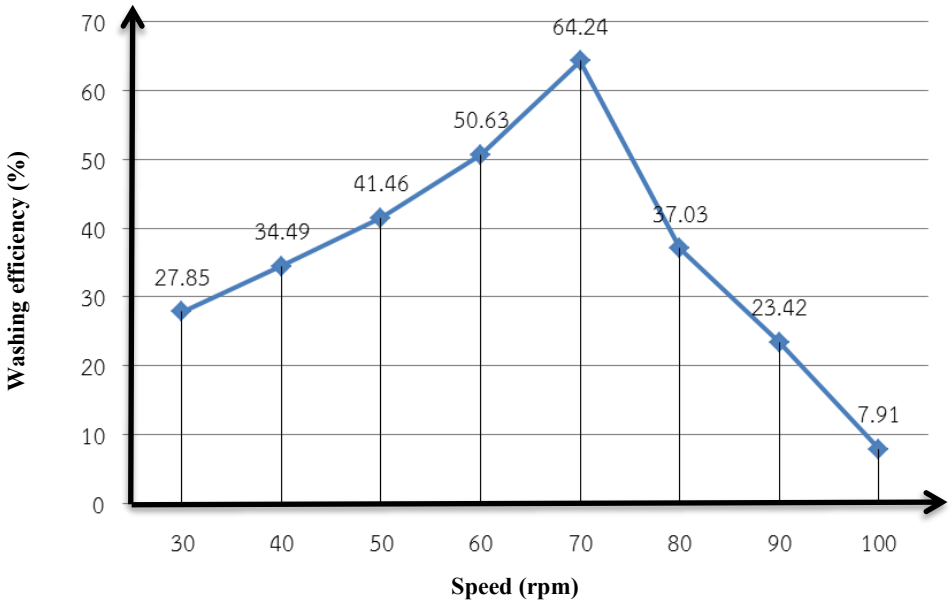


Figure 6 The washing efficiency

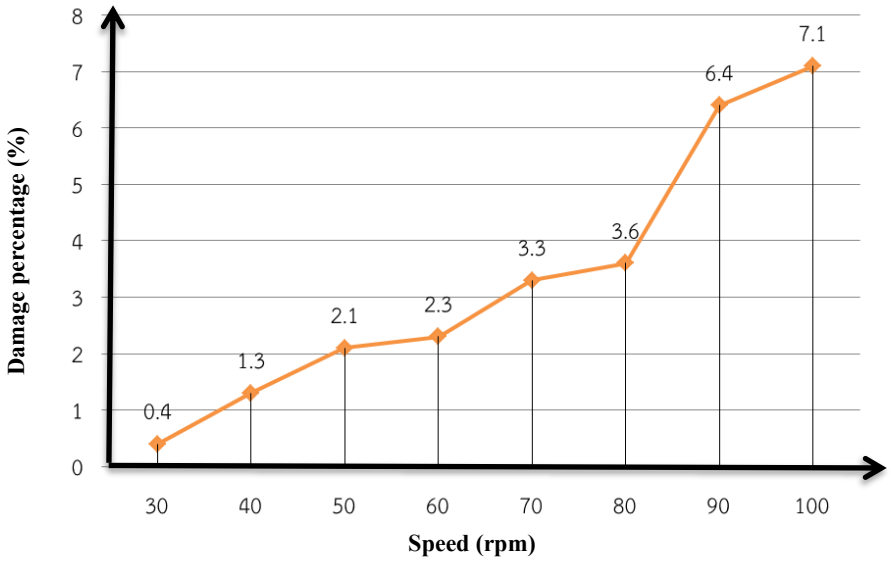


Figure 7 The percentage of damage

From the two graphs above, to achieve both a high washing efficiency and a low damage percentage, the researchers selected a speed range between 30 to 70 rpm; which the range of screen speeds used was derived from the development of a Jerusalem artichoke washing machine [10] and design of a rotating barrel carrot washing machine powered by a tractor [12].

2) Water Flow Rate Range

The development of this galangal washing machine focused on farmer use. Therefore, to facilitate water flow rate adjustment, five repetitions were conducted to determine the water flow rate at ball valve openings of 45, 60, and 90°. The results are shown in Table 1.

Table 1 Water flow rate at each angle of ball valve opening

Replication	Ball valve opening angle (Q ;l/min)		
	45°	60°	90°
1	9.89	20.79	31.76
2	11.21	19.42	30.87
3	9.78	20.19	29.96
4	10.32	19.78	30.54
5	10.24	20.89	29.13
Average	10.29 ± 0.56	20.22 ± 0.63	30.45 ± 0.99

where (Q ;l/min) is the water flow rate

From Table 1, the values of the three flow rates obtained for ball valve openings at 45°, 60°, and 90° are 10.29, 20.22, and 30.45 l/min, respectively, which will be used as a factor in the next study, which is lower than the study of the semi-automatic ginger cleaning machine [8] using a flow rate of 40 l/min.

2.4 Factors studied

The factors used in the study include 3 levels of rotating screen speed: 30, 50, and 70 rpm, which the range of screen speeds used was derived from the design of a rotating barrel Jerusalem artichoke washing machine by Srison et al. [10] and 3 levels of water flow rate: 10, 20, and 30 l/min.

2.5 Performance Testing

Galangal dug from farmers' plots was cut to approximately 5 cm long. Galangal was washed with a galangal washing machine (Figure 8) at 10 kg per time for 3 replications. The machine was set up according to the factors studied above. In every test, data on the weight of galangal before and after washing (Figure 9), the weight of damaged galangal after washing (Figure 10), and the washing time were recorded. The test data were used to calculate the performance of the galangal washing machine, which consisted of operating capacity, washing efficiency, and damage percentage, according to equations 1-3, respectively [9, 10, 13, 14, 15, 16]. The calculated results were then analyzed and compared with traditional galangal washing (Figure 11).

Figure 8 Washing galangal with a machine

(a) Galangal without washing

(b) Galangal after washing

Figure 9 Galangal without (a) and after (b) washing

Figure 10 Damaged galangal

Figure 11 Traditional galangal washing

$$\text{Operating capacity (kg/h)} = W_1/t \quad (1)$$

$$\text{Washing efficiency (\%)} = ((W_1-W_2)/(W_1-W_3)) \times 100 \quad (2)$$

$$\text{Damage percentage (\%)} = (W_4/W_3) \times 100 \quad (3)$$

where W_1 = the weight of fresh-harvested galangal fed to the machine per batch (kg)
W_2 = the weight of galangal collected at the outlet after machine washing (kg)
W_3 = the total weight of galangal after the complete washing by hand (kg)
W_4 = the weight of damaged galangal after complete washing by hand (kg)
t = the working time (h)

3. Results and discussion

The operating capacity, washing efficiency, and damage percentage of the machine at three speeds and water flow rates compared with the traditional farmers' washing is shown in Table 2 and Figure 12. When the speed increased, the operating capacity and the washing efficiency of the machine were naturally higher, averaging 81.86, 111.11, and 174.52 kg/h, and 24.37, 38.67, and 44.31 % at 30, 50, and 70 rpm, respectively. While the damage percentage of the machine decreased, averaging 0.21, 1.01, and 2.05 % at 30, 50, and 70 rpm, respectively.

Table 2 Average operating capacity, washing efficiency, and damage percentage of the machine at different speeds and water flow rates compared with the manual process

Speed (rpm)	*Q* (l/min)	Operating capacity (kg/h)	Washing efficiency (%)	Damage percentage (%)
30	10	81.08	17.82	-
	20	82.74	24.27	-
	30	81.76	31.01	0.63
	Ave.	81.86 ± 0.83	24.37 ± 6.60	0.21 ± 0.36
50	10	110.87	27.25	1.11
	20	110.11	31.27	0.57
	30	112.36	57.50	1.35
	Ave.	111.11 ± 1.14	38.67 ± 16.43	1.01 ± 0.40
70	10	175.30	27.88	2.12
	20	173.25	33.64	1.89
	30	175.01	71.42	2.15
	Ave.	174.52 ± 1.11	44.31 ± 23.65	2.05 ± 0.14
Average		122.50	35.78	1.09
Manual		33.22	90.95	0.08

where *Q* (l/min) is the water flow rate

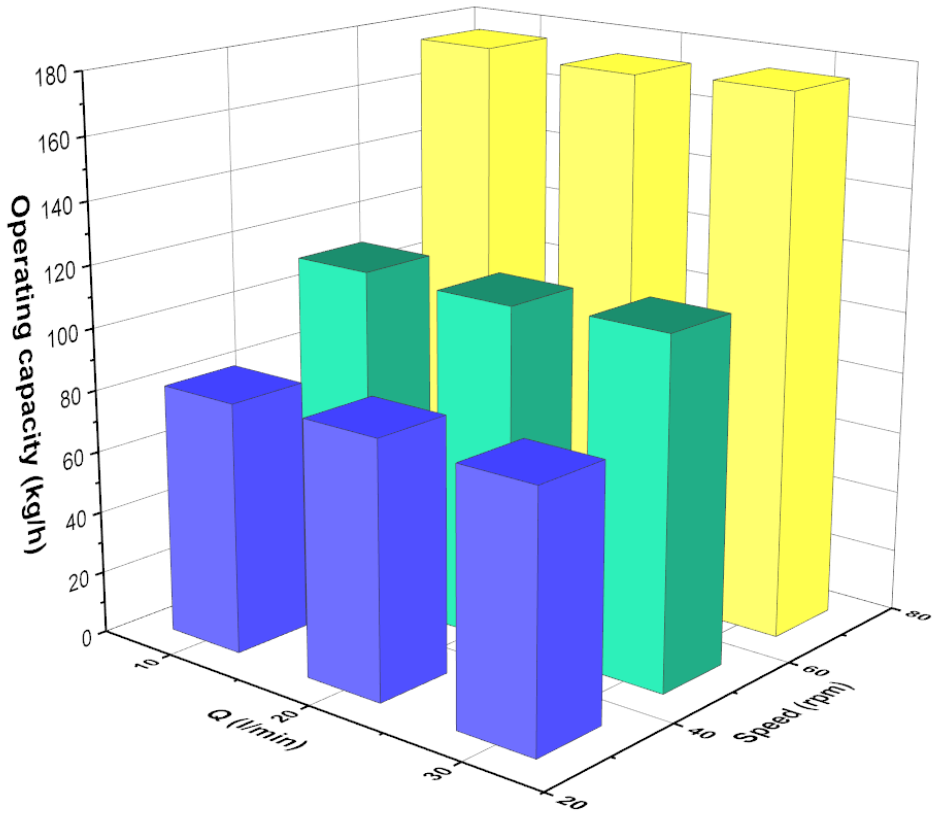


Figure 12 Graphical representation of the average operating capacity of the machine at three water flow rate and different speeds

From Table 2 and Figure 12, the water flow rate did not have an effect on the operating capacity of the machine. At a speed of 70 rpm and a water flow rate of 30 l/min, the highest values of operating capacity, washing efficiency, and percentage of damage were obtained. The comparison with farmers can be shown in a bar chart as in Figure 13-15.

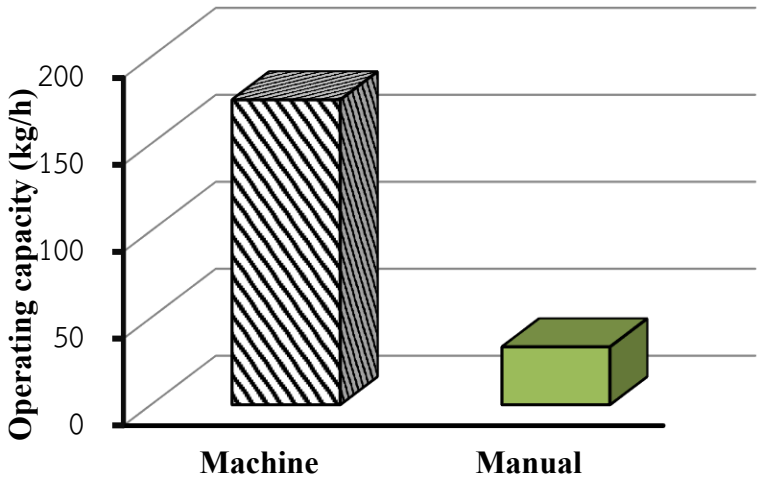


Figure 13 Graphical representation of the average operating capacity of the machine at speed 70 rpm and water flow rate 30 l/min compared with the manual process

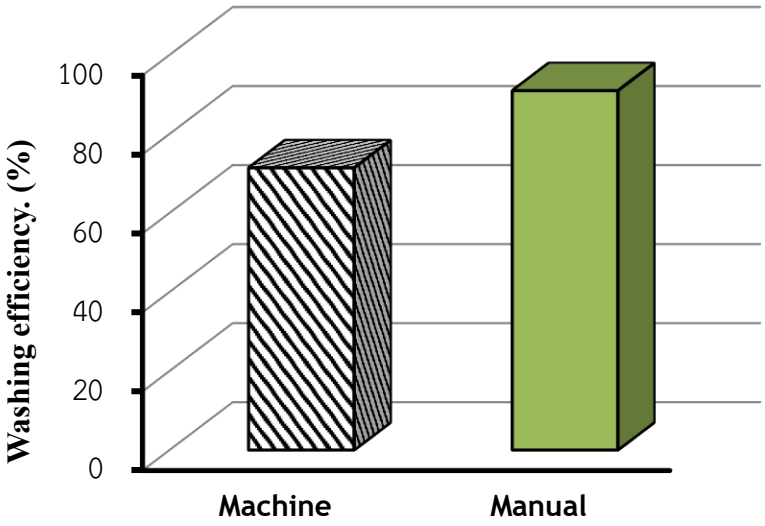


Figure 14 Graphical representation of the average washing efficiency of the machine at speed 70 rpm and water flow rate 30 l/min compared with the manual process

Figure 13 shows a performance comparison of the galangal washer at 70 rpm and a water flow rate of 30 l/min with manual washing. The average operating capacity was 175.01 and 33.22 kg/h, respectively. The operating capacity of the machine in this research cannot be compared with that of other research [8] [9] because the testing conditions differ significantly. For example, Poojeera and Khanthawithi [8] used a washing process with circulating water at a volume of 1.49 l/kg, resulting in an operating capacity of 36.09 kg/h. While the study of Promkesa et al. [9] used a vertical galangal washer with circulating water inside the tank, using a water volume of 2.67 l/kg, giving an operating capacity of 75 kg/h. While this research used an average washing water of 10.76 l/kg, giving an average operating capacity of 122.50 kg/h.

Figure 14-15 shows a performance comparison of the galangal washer at 70 rpm and a water flow rate of 30 l/min with manual washing. The average washing efficiency was 71.42 and 90.95 %, and the average damage percentage was 2.15 and 0.08 %, respectively. No studies on washing efficiency and damage percentage were found in Poojeera and Khanthawithi [8], Promkesa et al. [9] and Ketviriyakit et al. [17].

The advantage of the machine used in this research is that it operates optimally for washing fresh galangal at 70 rpm and a water flow rate of 30 l/min, achieving maximum operating capacity and washing efficiency while also resulting in a very high damage percentage. Specifically, although the machine provides a higher operating capacity (175.01 kg/h) than manual washing (33.22 kg/h), its washing efficiency (71.42%) is significantly lower than the manual process (98%), and its damage percentage (2.15%) is much higher than the manual process (0.08%).

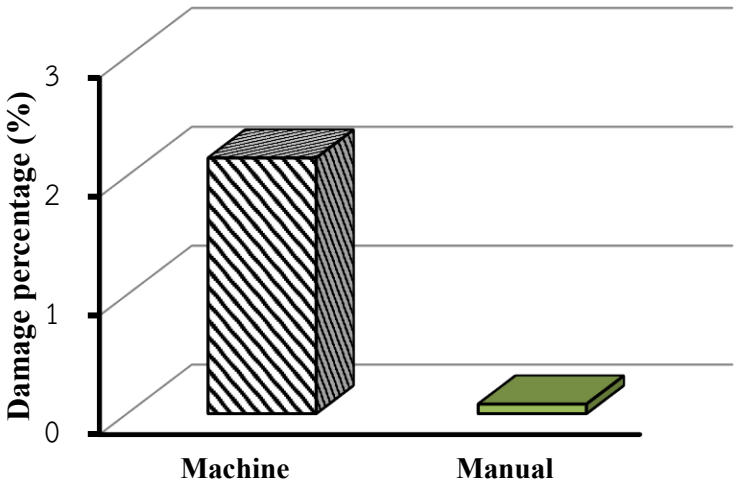


Figure 15 Graphical representation of the average damage percentage of the machine at speed 70 rpm and water flow rate 30 l/min compared with the manual process

4. Conclusions

The current work was designed and constructed for a fresh galangal (*Alpinia galanga* L.) washing machine by spraying pressurized water. Three machine speeds, 30, 50, and 70 rpm, along with three water flow rates, 10, 20, and 30 l/min, were evaluated. These results were compared with a manual washing process. The machine's operating capacity varied with its speed, as expected. Water flow rate did not affect the operating capacities of the machine. Respective average operating capacities of 81.86, 111.11, and 174.52 kg/h at 30, 50, and 70 rpm. The highest average washing efficiency of the galangal washing machine was 71.42% using a speed of 70 rpm and water flow rates of 30 l/min. However, the manual process has an average washing efficiency of 90.95%. While the average damage percentage of the machine is 2.15 % higher, the manual process is 0.08 %. Further research is needed to improve machine efficiency.

This machine design should also be improved to improve the washing performance in terms of washing efficiency and water savings. It is recommended to increase the washing time by using slower movements (based on rotational speed and fin angle) or increasing the tank length, and to add a water circulation and filtration system. A two-stage single-pass washing design could be considered. In the first stage, high-pressure spray and agitation can remove heavy soil and debris with recycled water. In the second stage, soft mechanical contact, such as nylon brushes or open-cell foam, combined with multi-angle spray using cleaner water, can gently improve the surface cleanliness of the galangal. This approach may increase the washing efficiency closer to manual washing while maintaining a low damage percentage and reasonable energy and water consumption. Such design refinements would add more engineering and practical value to the machine for real-world agricultural use.

5. Acknowledgements

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