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Development of a Jerusalem artichoke washing machine

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Abstract

The objectives of this research were to design and performance assessment of a Jerusalem artichoke washing machine. The expectation of this research was to raise production of Jerusalem artichoke to higher performance and safe work-times due to the shortage of labor in the agricultural sector. Due to the decline in agricultural labor caused by migration to urban areas, the use of machinery can compensate for the labor shortage and enable the remaining farmers to continue their operations. The components of Jerusalem artichoke washing machine are basin, barrel washing, water purifier, and water pump. Performance was evaluated from capacity, percentage of cleaning, percentage of damage and electric power. Three levels of barrel speed (17, 27 and 37 rpm) and two levels of time (5 and 10 min). The result showed that barrel speed significantly impacts all indicators. Time significantly impacts only electric power. The barrel speed was 27 rpm with time about 5-10 min were suitable operating factors of the Jerusalem artichoke washing machine, providing capacity, percentage of cleaning, percentage of damage and electric power about 4.93 kg/h, 57.20%, 9.47%, and 6.93 kwh, respectively.

Keywords: Jerusalem artichoke, Washing machine, Washing

1. Introduction

Cleaning is an important process for adding value to agricultural products. Most of the products are grown in soil, which causes soil or mud to stick to the surface of the product. In particular, plants with tubers under the ground must be washed before storage or sale [1]. Currently, there are various forms of washing agricultural products, such as spray washing, brush washing, and barrel washing. Washing of tubers such as potatoes, carrots, and sweet potatoes still mostly requires human labor. From a study of washing potatoes by human labor, it can work at 0.5-0.7 kg/min or 1 person can wash 20 kg of potatoes in 33 min. Before washing, the potatoes must be soaked in water for 15-20 min, then dried and packed in bags [2]. Farmers in Pakistan still use human labor to wash carrots, which takes quite a long time. Due to this problem, Rashid et al. [3] designed a carrot washer that uses tractor power to study the performance comparison between using human labor and machines in washing carrots. It was found that the machine has a higher time efficiency than using labor. It can be seen that the washing process takes a relatively long time. And it requires a lot of labor. Jerusalem artichoke is a plant with underground tubers, as shown in Figure 1. Jerusalem artichoke is high in inulin, a water-soluble fiber that promotes the growth of beneficial bacteria in the gut (prebiotic), supporting digestion and excretion [4]. It is a plant with significant potential to generate income for farmers as it can be processed into various products, such as tea, flour, dietary supplements, and health products, etc. It is a plant with the potential to generate income for farmers due to its high starch and sugar content and can also be used as a rotational crop in agriculture to reduce the use of chemicals in the soil and improve soil quality [5]. Jerusalem artichoke is considered a highly significant plant in terms of health, economy, and environment. With properties suitable for development in many dimensions, it also helps generate income for farmers and meets the needs of health-conscious consumers in the present era [4]. Harvesting can be done by using a shovel, hoe or hoe to dig and pull out by hand [6] and harvesting with a Jerusalem artichoke digger installed on a walking tractor [7]. After digging, the Jerusalem artichoke tubers must be washed with clean water, drained, and then put into plastic bags to store in a cold room at 5-10 ^{O}C [6]. Farmers in Hua Thale Subdistrict, Mueang District, Nakhon Ratchasima Province clean Jerusalem artichoke tubers by soaking the tubers in a large container for 15-20 min. Then, use a cloth to scrub off the dirt stuck in the crevices of the tubers, and then wash them with clean water again. The washed Jerusalem artichoke tubers are left to drain, then put into plastic bags and refrigerated to prepare for sale. The dug Jerusalem artichoke tubers must be washed and finished within the same day. This causes farmers to gradually dig up Jerusalem cores to suit the time and labor available each day. Each washing requires 4-5 people, who can work 10-15 kg/h. It can be seen that it takes a long time because most farmers use household labor, so there are few laborers and they are elderly. Currently, there is still a problem of labor shortage in the agricultural sector due to the expansion of the

industrial sector, resulting in labor migration to the industrial and service sectors. In addition, the remaining labor in the agricultural sector is quite old [8].

Figure 1 Jerusalem artichoke

From the above, it shows that washing Jerusalem artichoke cores by farmers requires a lot of time and labor. Currently, there is no machine that can wash Jerusalem cores to replace the labor shortage. Therefore, this research aims to design and evaluate the performance of a Jerusalem artichoke core washing machine, which may be a guideline to help farmers increase their yield and income from Jerusalem artichoke core production.

2. Methodology

2.1 Design of Jerusalem artichoke washing machine

The Jerusalem artichoke washing machine is designed to be a small machine that can be moved as shown in Figure 2. The machine structure is 120 cm wide, 240 cm long and 160 cm high, consisting of 6 main components:

1) The sink is made of galvanized steel sheet to prevent rust. It is rectangular in shape, 80 cm wide, 104 cm long and 50 cm high, and the bottom of the tank is covered with 4 mm thick polycarbonate sheet. It can hold up to 416 cubic centimeters of water.

2) The rotating grate is a wooden cylinder with a diameter of 60 cm and a length of 80 cm. The distance between the grates is 20 cm and there are openings and closing holes for taking Jerusalem artichoke in and out of the grate.

3) Water pressure pump use a 370 W water pump, PVC pipe of the whirlpool system size 2.54 cm, with a water filter to filter dirt before sending water through the pressure pipe to the water pressure release head.

4) Water filter set made from two plastic tanks, the first tank will filter large dirt or stones, and the second tank will filter small dirt.

5) Water delivery pipe is PVC pipe of the whirlpool system size 2.54 cm as a water delivery pipe of the whirlpool system, and use PVC pipe size 1.27 cm, length 80 cm as a water spray set with 4 water nozzles and a distance between the nozzles of 20 cm.

6) Power transmission set uses a 3-phase 1 hp AC electric motor with an inverter to control the speed of the electric motor. Using a belt to transmit power to the rotating grid.

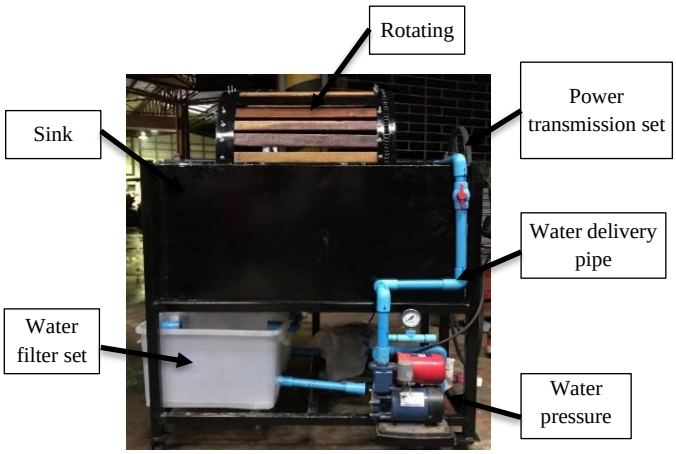

Figure 2 Jerusalem artichoke washing machine

The working principle of the artichoke washing machine is as follows: Fill the washing basin with water to a height of 40 cm from the bottom of the basin. Put the artichoke into the rotating grid. Soak the artichoke in water for the specified period of time. The rotating grid will be immersed in the washing basin about 20 cm high to cover the artichokes to be washed. Then press the switch to rotate the screen and turn on the water spray system at the same time to spray and clean the Jerusalem artichoke cores with soil stuck. Time the rotation of the screen and spray water for 3 minutes and then stop the machine. Then take out the washed Jerusalem artichoke cores to dry in the air and pack them in bags for storage or sale.

2.2 Factors studied and experimental design

The factors used in the study include 3 levels of rotating screen speed: 17, 27, and 37 rpm, which the range of screen speeds used was derived from the design of a rotating barrel carrot washing machine powered by a tractor by Rashid et al. [3] and 2 levels of water immersion time: 5 and 10 min, which are the time periods referred to from the study of washing Jerusalem cores of farmers in Hua Thale Subdistrict, Mueang District, Nakhon Ratchasima Province. The test plan was Factorial analysis in CRD, Two-way ANOVA.

2.3 Method of testing

1) Prepare Jerusalem artichoke cores By weighing 2 kg of Jerusalem artichoke core samples and adjusting the Jerusalem artichoke core washer according to the studied factors.

2) Add water to the washing basin to a water level of 40 cm from the bottom of the basin, then place the prepared Jerusalem artichoke cores into the rotating grid, close the lid, and soak the Jerusalem artichoke cores in water, starting the soaking time at 5 min.

3) Start testing the Jerusalem artichoke core washer using a grid speed of 17 rpm, timing the grid rotation for 3 min, stop the machine, and let the Jerusalem artichoke cores air dry, and test by changing the grid speed to 27 and 37 rpm, respectively.

4) Measure the electrical power using a wattmeter, which is a measuring device used to measure the electrical power (Power) of the Jerusalem artichoke core washer test.

5) Sort the Jerusalem artichoke cores after washing by separating them into clean Jerusalem artichoke cores, unclean Jerusalem artichoke cores, and bruised Jerusalem artichoke cores, as shown in Figure 3. Then weigh the clean and bruised Jerusalem artichoke cores, and wash the unclean Jerusalem artichoke cores and air dry them.

6) Test the Jerusalem artichoke kernel washing machine by changing the soaking time to 10 min and perform the same tests as in items 3), 4) and 5) respectively.

7) Analyze the obtained data to find the working capacity, cleanliness percentage, damage percentage and electric power according to equations 1, 2, 3 and 4 respectively.

- Working capacity (kg/h) $= W_C/t$ (1)

- Cleanliness percentage (%) $= W_C/W_T \times 100$ (2)

- Damage percentage (%) $= W_D/W_T \times 100$ (3)

- Electric power (kWh) $= (P \times t)/1000$ (4)

where W_C = the weight of clean Jerusalem artichoke kernel (kg)
W_D = the weight of damaged Jerusalem artichoke kernel (kg)
W_T = the total weight of Jerusalem artichoke kernel (kg)
t = the working time (h)
P = the electric power (W)

a) b) c)

Figure 3 a) Cleaned b) Uncleaned c) Damaged

3. Results and discussion

The results of statistical analysis of the rotating screen speed and time on the working capacity, cleanliness percentage, damage percentage, and electrical energy were analyzed using the Factorial analysis in CRD test plan. Two-way ANOVA was used. The details of the study are as follows:

3.1 Working capacity (kg/h)

The effects of rotating screen speed and time on the working capacity of the Jerusalem artichoke washing machine are shown in Table 1.

From Table 1, the variance of rotating screen speed and time on the working capacity were analyzed as shown in Table 2. It was found that the rotating screen speed had a significant effect on the working capacity statically, but time and the interaction between rotating screen speed and time did not have a significant effect on the working capacity statically. The rotating screen speed of 37 rpm gave the highest working capacity. The ideal time for soaking Jerusalem artichoke kernels before washing was 5-10 min because it had the highest working capacity of 5.62-6.35 kg h-1 when the rotating screen speed increased. The working capacity tends to increase, as shown in Figure 4, which is consistent with the research of Rashid et al. [3].

Table 1 the capacity (kg/h) at three different barrel speed and two different time

Time (min)	Barrel speed (rpm)		
	17	**27**	**37**
5	3.50	4.93	6.35
10	3.07	4.22	5.62

Table 2 Analysis of variance barrel speed and time affecting the capacity (kg/h)

SOV	df	SS	MS	F
Barrel speed (A)	2	27.762	13.881	43.883*
Time (B)	1	77.087	77.087	243.701ns
A x B	2	1.597	0.799	2.525ns
Error	12	3.796	0.316	
Total	18	1680.296		

Note: * Significant ($p<0.05$), ns Non-Significant.

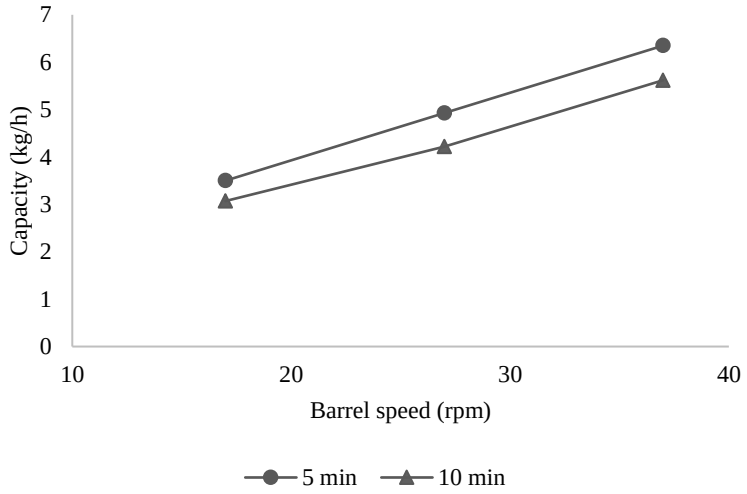

Figure 4 Relationships between barrel speed and time affecting capacity

3.2 Percentage of cleanliness

The effect of wind speed and time on the percentage of cleanliness of the Jerusalem artichoke kernel washer is shown in Table 3.

Table 3 The percentage of cleaning at three different barrel speed and two different time

Time (min)	Barrel speed (rpm)		
	17	**27**	**37**
5	32.08	44.49	64.16
10	42.59	57.20	68.21

From Table 3, the variance of the rotating screen speed and time on the percentage of cleanliness is analyzed, as shown in Table 4. It was found that the rotating screen speed has a significant effect on the percentage of cleanliness statically, but time and the interaction between the rotating screen speed and time do not have a significant effect on the percentage of cleanliness statically. The screen speed of 37 rpm gives the highest percentage of cleanliness. The ideal time for soaking Jerusalem artichoke kernels is 5-10 min because it has the highest percentage of cleanliness, which is 64.16-68.21%. When the rotating screen speed increases, the percentage of cleanliness tends to increase, as shown in Figure 5.

Table 4 Analysis of variance barrel speed and time affecting the percentage of cleaning

SOV	df	SS	MS	F
Barrel speed (A)	2	2511.141	1255.571	28.439*
Time (B)	1	344.531	344.531	7.804ns
A x B	2	71.039	35.520	0.805ns
Error	12	529.789	44.149	
Total	18	51453.815		

Note: * Significant ($p<0.05$), ns Non-Significant.

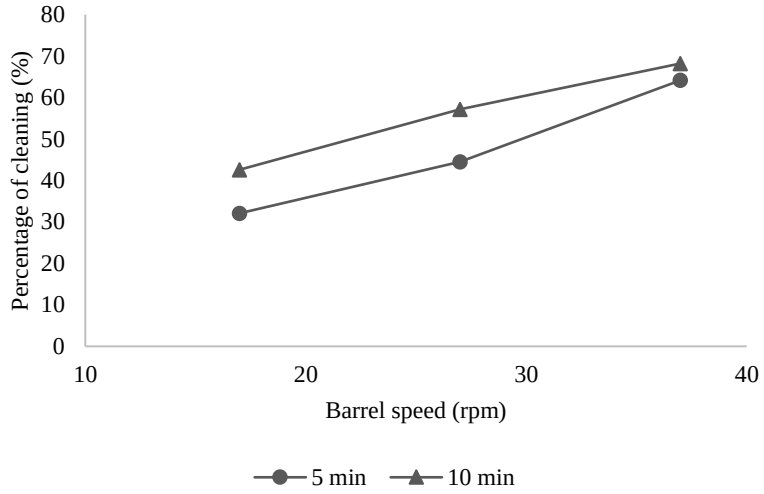

Figure 5 Relationships between barrel speed and time affecting percentage of cleaning

3.3 Percentage of damage

The effect of wind speed and time on the percentage of damage of Jerusalem artichoke washing machine is shown in Table 3.

Table 3 The percentage of damage at three different barrel speed and two different time

Time (min)	Barrel speed (rpm)		
	17	**27**	**37**
5	4.00	9.47	34.56
10	5.15	12.34	28.41

From Table 3, the variation of rotating screen speed and time on the percentage of damage is analyzed as shown in Table 4. It was found that rotating screen speed has a significant effect on the percentage of damage statically, but time and the interaction between rotating screen speed and time have no significant effect on the percentage of damage statically, where the screen speed of 17 rpm gives the lowest percentage of damage. The ideal time for soaking Jerusalem artichoke seeds is 5-10 min because it has the lowest percentage of damage, which is 4.00-5.15%. When the rotating screen speed increases, the percentage of damage tends to increase, as shown in Figure 6.

Table 4 Analysis of variance barrel speed and time affecting the percentage of damage

SOV	df	SS	MS	F
Barrel speed (A)	2	2417.947	1208.973	90.426^{*}
Time (B)	1	3.772	3.772	0.282^{ns}
A x B	2	73.776	36.888	2.759^{ns}
Error	12	160.438	13.370	
Total	18	2655.932		

Note: * Significant ($p<0.05$), ns Non-significant.

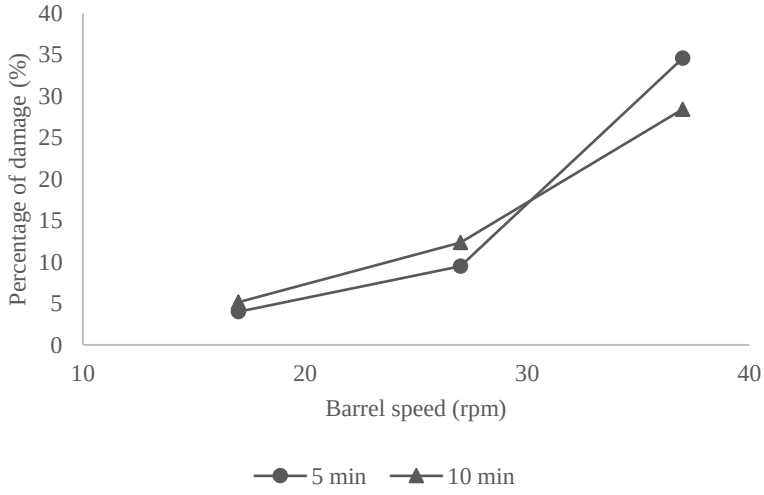

Figure 6 Relationships between barrel speed and time affecting percentage of percentage of damage

3.4 Electric power

The effect of wind speed and time on the electric power of the Jerusalem seed washer is shown in Table 5

Table 5 The electric power at three different barrel speed and two different time.

Time (min)	Barrel speed (rpm)		
	17	**27**	**37**
5	6.23	6.93	8.66
10	9.53	11.51	13.19

From Table 5, the variation of rotating screen speed and time on electric power is analyzed, as shown in Table 6. It was found that the screen speed and time have a significant effect on electric power statically, but the interaction between rotating screen speed and time has no significant effect on electric power statically, where the rotating screen speed of 17 rpm gives the lowest electric power. The time used for soaking Jerusalem kernels before washing for 5-10 min has an electrical energy value of 6.23-9.53 kWh. When the rotating sieve speed and time increase, the electrical energy tends to increase as shown in Figure 7.

Table 6 Analysis of variance barrel speed and time affecting the electric power

SOV	df	SS	MS	F
Barrel speed (A)	2	27.762	13.881	43.883*
Time (B)	1	77.087	77.087	243.701*
A x B	2	1.597	0.799	2.525ns
Error	12	3.796	0.316	
Total	18	1680.926		

Note: * Significant ($p<0.05$), ns Non-Significant.

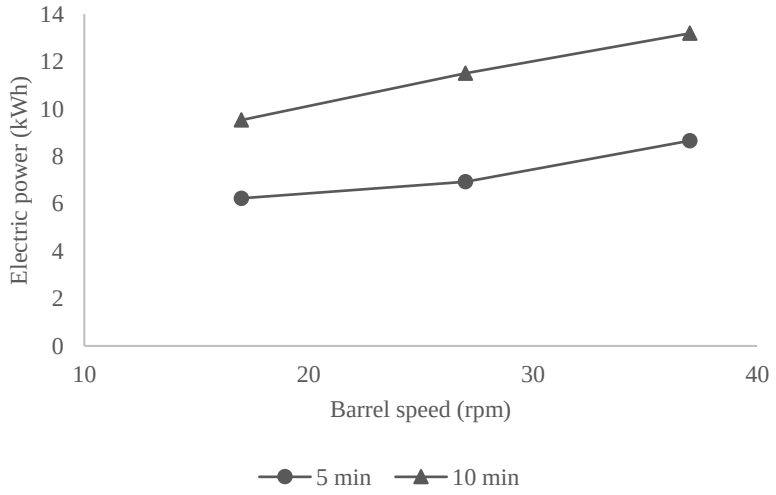

Figure 7 Relationships between barrel speed and time affecting electric power

4. Conclusions

Design and performance evaluation of Jerusalem artichoke washing machine to solve the problem of labor shortage in agriculture. The Jerusalem artichoke washing machine consists of washing basin, rotating screen, water filter and water pressure pump. The study was conducted at 3 levels of rotating screen speed: 17, 27 and 37 rpm and 2 levels of water immersion time: 5 and 10 min. The performance of the Jerusalem artichoke washing machine was evaluated from the working capacity, cleanliness percentage, damage percentage and electric power. The results of the study found that the rotating screen speed has a statistically significant effect on the working capacity, cleanliness percentage, damage percentage and electric power. The water immersion time has a statistically significant effect on electric power but has no statistically significant effect on the working capacity, cleanliness percentage and damage percentage. The interaction between the rotating screen speed and time has no statistically significant effect on the working capacity, cleanliness percentage, damage percentage and electric power. The rotating screen speed of 27 rpm and the immersion time of 5-10 min are the most suitable for the Jerusalem artichoke washing machine, which has a working capacity of 4.93 kg/h, a cleanliness percentage of 57.20%, a damage percentage of 9.47% and an electric power of 6.93 kwh.

5. Acknowledgements

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