Comparative Study of Manual Washing and Galangal Machine Washing: A Case Study of Uttaradit Province, Thailand.

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Abstract

Price fluctuation of agricultural products in Thailand is caused by several factors such as market demands, economic downturns, increasing oil prices, and the COVID-19 pandemic, which directly impacts employment and labor for galangal producers Uttaradit. The high labor cost for washing galangal, rising shipping costs, and health problems faced by farmers from galangal washing led the research team to see the significance of these problems. Consequently, the research team applied engineering knowledge to the design and construction of a galangal washing machine that is suitably sized for the farmers of Nang Phaya Sub-district, Uttaradit Province, and to study the payback period for the galangal washing machine through comparison with current labor use to determine whether the device is suitable for investment and actual application. According to the findings, the galangal washing machine that replaces traditional washing with manual labor can reduce galangal production costs by 773.07 Baht per day, with the payback period for the galangal washing machine at 88.04 days. Furthermore, the galangal washing machine has an effective capability to support future galangal production growth of as much as 5,000 kilograms per day. With a payback period of only 3 months, this machine can enhance the agricultural production of galangal farmers to increase income while also improving occupational health.

Keywords
Galangal Washing Machine, Payback Period, Machine Design

1. Introduction
With the changes in Thai society due to ongoing globalization, farmers face difficulties caused by economic, social, and political changes. Numerous problems currently exist, such as production and resources, health, technologies, and marketing, which have caused impacts in multiple dimensions, such as farmers' increasing shift toward energy crops and monoculture. Moreover, changes in farming systems are leading to a decline in the number of small-scale farmers, and today's galangal farmers in Uttaradit in the northern region of Thailand are facing these problems since they so far have been unable to adopt various suitable technologies to help resolve production problems consistently with increasing production. As a result, they suffer from galangal production planning for sale problems in time to meet consumer demands. Furthermore, the heavy reliance on manual labor in traditional production processes and increasing production costs have also caused many planning and operational problems. Therefore, this research presents an analysis of investment that compares galangal washing by manual labor with galangal washing by using a semi-automatic machine to reduce the labor required in the washing process and increase product effectiveness, including the volume of galangal washed per day. The structure of this research is composed of section 1 Introduction, section 2 galangal at Nang Phaya Sub-district, second 3 related theories and research, second 4 research findings, and section 5 conclusions and recommendations.

2. Galangal

At Nang Phaya Sub-district, Uttaradit Province, over 1,000 rai of galangal are grown. The galangal grown is Alpinia officinarum or what the locals call "Kha Gaeng." It is a species of galangal that has ever since the past grown naturally along foothills. The rhizomes are large and have a spicy flavor and intense fragrance, making them suitable for commercial processing. It is in high demand in the industrial sector, and it is also processed into dry galangal that is used as an ingredient in the production of herbal medicines.

Moreover, it can be made into powdered galangal for use in the food processing industry. Over 500,000 kilograms of galangal are produced at Nang Phaya Sub-district annually. Thus, production is a primary occupation that has supported the local people for decades.

Figure 1. Wild Galangal or Alpinia Officinarum

Retrospective data on production and sales of the farmers' galangal going back 52 weeks or from January to December 2020 show continuous increases, except during the rainy season when production declines (Weeks 2340) due to heavy rains and the characteristics of the highland foothill nature which prevent galangal harvest, as shown in Figure 2.

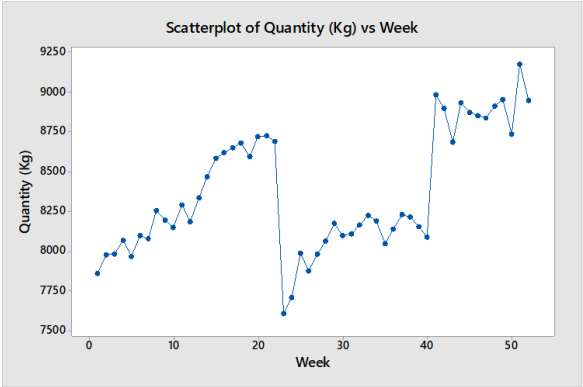

Figure 2. Data on the Production and Processing of Galangal in 2020

3. Research Methodology

3.1 Related Research

In agricultural management, many researchers solved problems by applying engineering principles in the development of agricultural machinery in Thailand and abroad, such as the following:

In 2007 Department of Agriculture, Manufacturers of processed curry ingredients, which is a domestic and international production and distribution industry, are currently facing problems associated with the cleaning of components for the production of curry ingredients such as galangal, ginger, onions, garlic, and kaffir limes, especially as they relate to soil contamination. Thus, it is necessary to wash ingredients before market distribution. The current method used in washing is the piling of elements together and then using a hose to spray water to remove soil and contaminants. This washing method causes damage to the ingredients. It requires significant labor, leading private

companies to order washer machines featuring conveyor belts and water sprayers, but these are very expensive. As a result, the Department of Agriculture designed and developed a ginger washing machine capable of washing ginger cleanly without causing damage. The device has simple mechanics and uses materials readily available for purchase in the country. In addition, the machine can wash ginger at the rate of 1 ton per hour, as it is connected to a water pump capable of pumping 450 liters of water per minute at 300 psi of pressure. Cahyaningrum et al. (2015) analyzed the effectiveness of a herb chopping machine to support sustainable farming. The study found that the device could be chopping galangal at the rate of 17.28 kg. /hr. Ginger by 24.92 kg./hr. And turmeric by 29.69 kg. /hr. The chopping machine's effectiveness was 98.25% for galangal, 97.67% for ginger, and 98.58% for turmeric. Phimpha (2017) on the construction of a machine for washing sweet potatoes by the use of water pressure and a dry-baking unit – The findings revealed that the device for washing sweet potatoes and the dry-baking team were able to reduce the number of manual laborers by 1 with a work cost reduction by 169 Baht per day and increased productivity by 5,760 kilograms per day. Pruengam et al. (2017) designed, developed, and constructed a roller brush and water pressure plant washing machine to use the device to promote agricultural productivity and reduce labor work burden in washing while cutting cost in the ordering of expensive foreign machinery. The engine was used to wash two plants, namely, sugar, galangal, and potato. The study concluded that a speed of 300 RPMs could pass galangal at the rate of 507.5 kilograms per hour and 727.8 kilograms of potatoes per hour. Thus, the plant washing machine sped up work while cutting production costs. Kumar et al. (2019) proposed a washing-cum-peeling machine for a production line of bleached dry ginger. The machine used two hard nylon brush rollers that rotated at 200 rpm in the opposite direction. The machine required one unskilled laborer to collect the rough peeled rhizomes after each batch of operations. The result showed a saving of 42.3% of labor and 46.7% of time. Oluka et al. (2019) selected field agricultural machinery to improve farm work in eastern Nigeria. The study found that the mean work effectiveness of rice cultivators in the south to east Nigeria was 87.11%, while rakes, dikes, disc plows, and farmers had 86.32%, 86.78%, 87.14%, and 86.81%, respectively. Ketwiriyakit et al. (2020) studied guidelines for developing agricultural technologies for galangal growers as a case study in Nang Phaya Sub-district, Uttaradit, covering the internal and external factors influencing galangal production. For internal factors, it was found that farmers gave the most important to the cleaning or processing of produce before sales, with a mean at 4.53, followed by obstacles and complications in work procedures, with a mean at 4.42, while for external factors, it was found that, on health, environmental conditions caused eye fatigue, with the highest mean score at 4.61, followed by technological limitations in the machinery used in product cleaning, with mean at 4.30. Patel and Ahuja (2020) studied and researched agricultural equipment designs related to rice fields and found that the machinery was cumbersome and expensive in most activities involving machinery. Farmers were farmers unable to purchase expensive machinery. The finding also showed that small and medium-sized machinery was more suitable, affordable, and effective than large machinery. Anveer et al. (2020) designed and invented an all-purpose farming vehicle. The project aimed to design and develop a utility vehicle to support farming processes such as plowing, sowing, weed removal, pesticide spraying, and soil leveling. This project used a rechargeable battery and motor, and a disc plow was installed for soil preparation, and a chemical pump was also installed for spraying pesticides. Poojeera and Khanthawithi (2021) developed a galangal cleaning machine to reduce the cleaning problems. The difference between before and after cleaning was 0.9 kg, or 18%. The payback period was 6 months when compared with labor costs. The literature review of related research showed that engineering designs could reduce losses in production, shorten the time and increase work effectiveness while effectively maintaining product quality. In the management of other agricultural areas, linear programming was used in agricultural management (Ruekkasaem and Sasananan 2018), including image processing for identification of plant disease problems (Liu and Wang 2021; Devaraj et al. 2019) and artificial intelligence or AI for problem-solving (Kamdar et al. 2021; Singh 2018) and processing problems by the use of metaheuristics, along with many other methods such as Harmony search algorithm (HSA) (Aungkulanon et al. 2012), Elevator kinematic Optimization (EKO) (Aungkulanon et al. 2018) and Biogeography-based Optimization Algorithm (BBO) (Aungkulanon et al. 2020).

3.2 Conceptual Framework

Conceptual Framework for the Design of the Galangal Washing Machine – The development of the washing machine for the galangal of Nang Phaya involved the application of engineering principles in designing and promoting agricultural production processes. Knowledge, ideas, principles, techniques, procedures, methods, and scientific works, including inventions, were applied in the work system to facilitate increased work effectiveness and enhanced quality of galangal processing. Brainstorming activities involving related parties were relied upon by the use of the 4M 1E concept, which consists of a group of factors for the identification of various causes, namely, M Man or the laborers involved in the washing and processing of galangal, M Machine or the machinery or equipment for facilitating the washing of galangal, M Material or the raw materials or parts and accessories used in the washing of galangal, and

M Method or the work processes in the washing of galangal, and 1 E Environment or the environment in which galangal washing occurs at Nang Phaya Sub-district. The conceptual framework is shown in Figure 3.

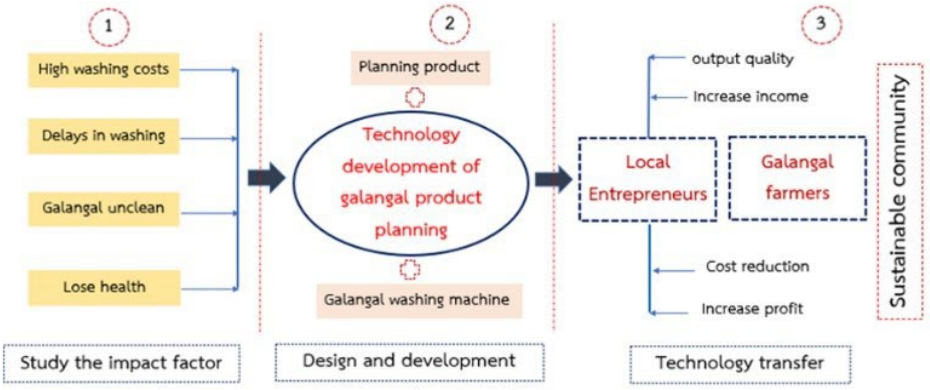

Figure 3. Conceptual Framework in the Design of the Galangal Washing Machine.

3.3 Analysis of the Payback Period

Analysis of the Payback Period – Estimated time in years for the return of investment equals the amount of money initially invested in the purchase of the machinery as calculated based on the cost for the purchase of the machinery divided by the new benefits expected to be received from the use of the machinery as calculated from Equation (1).

$$PBP = P/R \quad (1)$$

PBP = Payback Period
P = Machine Cost (BAHT)
R = Benefits or Reduction cost (Baht)

4. Numerical Results

The study of the galangal processing processes in Nang Phaya Sub-district, Uttaradit Province, covered techniques ranging from harvesting of the galangal rhizomes or what is known as "Kha Din" by digging them up from the soil and then washing them, which is an essential preliminary processing step, until the galangal rhizomes are clean, which are then called "Kha Hua," that are then ready for sale or processing into other products.

4.1 Galangal Production

Galangal Production by Farmers in Nang Phaya Sub-district – Galangal has to be 1-2 years old. All of the stalks of entire clumps of galangal are cut down to a length of 15-20 centimeters. Then hoes are used to dig around the base of the clusters. Then spades remove the rhizomes and leave only 7-8 galangal rhizomes in the soil. The mature galangal is removed and shaken to remove dirt. Knives are then used to remove the roots of the galangal and keep only the rhizomes. The rhizomes are then washed by a high-pressure water sprayer one rhizome at a time by slowly rotating the rhizomes to ensure that the rhizomes are thoroughly cleaned. Then the galangal rhizomes are packed into 8.5kilogram nylon bags for distribution in Uttaradit or general sales at the price of 12 Baht per kilogram and packed into 10.1-kilogram bags for transportation by trucks transporting 4,200-4,600 kilograms of them for sale at Talad Thai in Bangkok for a price of 16 Baht per kilogram.

At present, washing galangal by manual labor is slow, and no more than 400 kilograms of galangal can be washed per day. Moreover, washers commonly suffer from several health problems such as hand and foot disease, back pain from long hours of sitting, blurred vision from visual inspections, and burning sensations in the eyes and throat from smelling galangal, as shown in Figures 4 and 5.

Figure 4. Washing Galangal by Manual Labor by Spraying Jet Water

Figure 5. Farmers' Galangal Produce Washed for Distribution as Kha Hua and Dried Galangal Slices

4.2 Galangal Washing Machine

This machine comprises a structure sized 1.32 x 3.26 x 2.2 meters with a wash grate diameter of 1.2 meters and a high-pressure pump sized 30 kg. /cm^2. A total of 12 stainless steel water sprayers sized 0.04 millimeters are used, and in washing, the Kha Din is loaded fully into plastic baskets, then poured into a tray for receiving the galangal. Six baskets per time do this. Then the galangal is transported into the grate, which rotates at a speed of 6.5 RPMs to flip it back and forth in line with the grate's rotation. Cleaning is done for 20 minutes using the high-pressure sprayers distributed inside, and then the galangal is released on the other side of the machine where mesh bags wait for packaging, as shown in Figure 6-8.

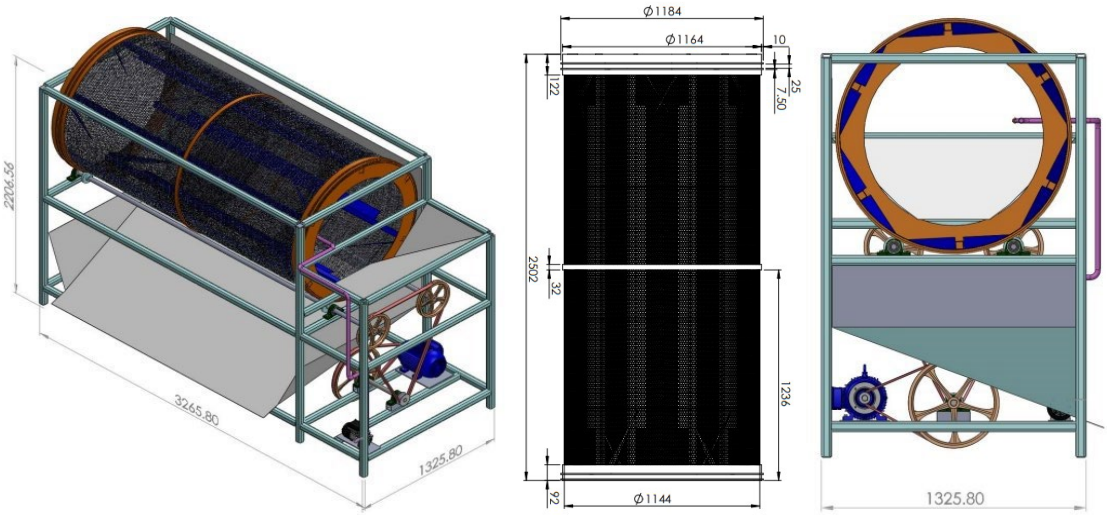

Figure 6. Drawing from SolidWorks program

Figure 7. Steel Structure of Washing Machine

Figure 8. Galangal Washing Machine and Products

4.3 Calculation of the Payback Period from Galangal Washing

Data collected into the galangal-washing in the galangal farmers of Nang Phaya Sub-district between the use of manual labor and the galangal washing machine were used to calculate costs and the payback period as follows:

4.3.1 Cost for Washing Galangal by Manual Labor

Data on washing from January to March 2021 revealed that the average amount of galangal produces sold by the galangal farmers of Nang Phaya Sub-district, Uttaradit, was 9,624 kilograms per week, whereby galangal was washed for six days per week by four laborers to wash 1,604 kilograms of galangal per day with 7 hours of work per day. Washing was performed using four high-pressure water pump motors sized 746 watts capable of pumping 35 liters per minute. Each machine consumed 12-13 cubic meters of water per day, with the unit price of water at 6 Baht and the unit price of electricity at 3 Baht, paid according to actual use. Thus, the cost for washing by manual labor was calculated as shown in Table 1.

Table 1. Estimated Cost of Manual Washing per week

Day	Worker	Total Weight (Kg./day)	Total Cost of Manual Washing per day					
			Labor (Baht)	Water (Unit)	Water Cost (Baht)	Electrical (Unit)	Electrical cost (Baht)	Total Cost (Baht)
1 (08.00-16.00)	1	398.7	300	12.8	76.8	3.98	11.94	388.74
	2	400.4	300	13.4	80.4	4.43	13.29	393.69
	3	411.3	300	11.7	70.2	4.89	14.67	384.87
	4	401.2	300	11.3	67.8	4.61	13.83	318.44
	Total	1,611.6	1,200	49.2	295.2	16.9	53.73	1,550.73
2 (08.00-16.00)	1	388.5	300	12.2	73.2	3.88	11.64	384.84
	2	397.6	300	11.4	68.4	4.53	13.59	381.99
	3	405.6	300	13.8	82.8	4.79	14.37	397.17
	4	402.7	300	13.1	78.6	4.71	13.13	391.73
	Total	1,594.4	1,200	50.5	303.2	16.9	52.73	1555.93
3 (08.00-16.00)	1	378.9	300	11.9	71.4	3.78	11.34	382.74
	2	412.7	300	13.4	80.4	4.66	13.98	394.38
	3	407.5	300	13.7	82.2	4.89	14.67	396.87
	4	401.2	300	12.8	76.8	4.67	14.01	390.81
	Total	1,600.3	1,200	51.8	310.8	16.9	54.00	1,564.8
4 (08.00-16.00)	1	403.2	300	12.9	77.4	4.54	13.62	391.02
	2	400.2	300	12.2	73.2	4.74	14.22	387.42
	3	396.5	300	11.3	67.8	3.98	11.94	379.74
	4	399.3	300	12.1	72.6	4.38	13.14	385.74
	Total	1,599.2	1,200	48.5	291	16.9	52.92	1543.92
5 (08.00-16.00)	1	397.8	300	13.8	82.8	3.91	11.73	394.5
	2	404.3	300	11.6	69.6	4.54	13.62	383.22
	3	407.2	300	12.5	75	4.96	14.88	389.88
	4	399.3	300	13.2	79.2	4.38	13.14	392.34
	Total	1,607.6	1,200	51.1	306.6	16.9	53.52	1560.12
6	1	403.9	300	14.8	88.8	4.79	14.37	403.17

(08.00-16.00)	2	397.7	300	11.7	70.2	4.12	12.36	382.56
	3	412.1	300	13.5	81	4.98	14.82	395.82
	4	399.2	300	13.1	78.6	4.65	13.95	392.55
	Total	1,610.6	1,200	53.1	318.6	16.9	55.55	1,574.15
Summary		9624.6	7,200	251.1	1,825.4	101.4	304.2	9329.6
Average/day		1,604.1	1,200	50.7	304.2	17.90	53.72	1,557.92

4.3.2 Cost for Washing Galangal by Using the Galangal Washing Machine

From the average galangal amount of 9,624 kilograms per week, galangal was washed by the machine by six days per week or 1,604 kilograms per day. The device could clean 150 kilograms per time, with six baskets weighing 25 kilograms loaded per time. Two operators were employed, and the galangal washing machine functioned by using one high-pressure pump system sized 107 liters per minute. In addition, 12 spray nozzles were distributed in the device, and a pump motor sized 2,238 watts was used along with a motor sized 373 watts to drive the grill container to flip the galangal. Each washing session required 20 minutes per cycle or a rate of 450 kilograms per hour. Thus, only 4 hours were used in washing per day. The machine consumed 11 cubic meters of water per day, with a unit price of water at 6 Baht and a unit price of electricity at 3 Baht, paid according to actual use. Current testing of washing machine by Clamp Meter was shown in figure 8. The cost in the production of galangal by using the galangal washing machine was calculated as shown in Table 2.

4.3.3 Payback Period (PBP)

PBP = cost for the construction of the galangal washing machine/(cost from washing by manual labor – cost from washing by using the galangal washing machine) PBP = (65,000) / (1,557.92- 784.85) = 84.08 day

Table 2. Average Cost of 1 week by Washing Machine

Day	No. of Worker	Total Weight (Kg/day)	Labour (Baht)					
			Labour (Baht)	Water (Unit)	Water Cost (Baht)	Electrical (Unit)	Electrical cost (Baht)	Total Cost (Baht)
Average/day	2	5,025	23.2	23.2	139.2	15.22	45.65	784.85

Figure 8. Current Testing of Washing Machine by Clamp Meter

5. Conclusion and Future Work

Currently, the agricultural area of Nang Phaya Sub-district, Uttaradit Province, is continuously increasing the cultivation and processing of galangal by up to 9,624 kilograms per week. This is in response to market demands in the industrial sector, which is interested in the galangal of Nang Phaya Sub-district for its large size, strong fragrance, and good flavors, and galangal farming has always been the primary occupation of the local people. Therefore, the design and construction of the galangal washing machine can enhance production potential. The study found that it can reduce the number of human resources involved in galangal washing from 4 to 2 persons, thereby saving 600 Baht in labor costs per day. In addition, the machine was able to shorten working duration from 8 to 4 hours and further reduce electricity consumption by 16.792 Baht per day and water consumption by 8.07 Baht per day, corresponding to average total production cost reduction in galangal washing by 773.07 Baht per day or 241,198 Baht per year.

Moreover, the payback period is only 88.04 days. The galangal washing machine is capable of supporting over 3,600 kilograms per day of production, thereby providing an opportunity to expand production capabilities to compete in the national market while increasing the confidence of industrial factors that buy the products and increasing the income of local farmers as a result of lower production cost and growing galangal cultivation areas, which can lead to sustainability in the occupations of the local people. Because galangal-washing is an essential preliminary processing process, studies should be conducted into utilizing natural clean water from Nang Phaya streams in the washing process to cut production costs further. Moreover, other types of machinery should be designed to cut galangal production costs, such as galangal slicers, bakers, and powder makers, which will help enhance the value of Nang Phaya galangal produce, and studies should be conducted into the design of the experiment (Luangpaiboon et al. 2019; Aungkulanon et al. 2021) and supply chain system for further galangal production planning (Pramasari and Hariyati, 2018) and scheduling (Ruekkasaem et.al.2021).

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Biography

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