Design and Fabrication of Small-Scale Potato Peeling Machine with Lye Method

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Abstract. Peeling or removing the skin is one of the main post-harvest processes in fruits and vegetables. At present, most of the peeling of fruits and vegetables is done manually using sharp objects / knives. This method of peeling causes more fruit flesh to be wasted, especially fruits / vegetables with thin skins. Therefore, the design of a machine that can peel thin-skinned fruits / vegetables using the lye peeling method is needed. The purpose of this study was to design and fabrication a machine that can peel fruits and vegetables after the pre-treatment process of soaking in hot NaOH. The way this machine works is by spraying pressurized water on the fruit soaked in hot NaOH solution. In this study, the object was potatoes. Control of water pressure coming out of the nozzle is done using the pulse width modulation (PWM) method with a potentiometer. The treatments were carried out using three duty cycle values with the analogue input setting value on the microcontroller which resulted in three variations of water pressure coming out of the nozzle, namely: 60% (4.2038 Pa); 80% (5.6051 Pa); and 100% (7,0065 Pa). Respectively for low, medium and high levels. Treatment concentrations of NaOH were 9%, 11% and 13%. The results obtained were the percentage of perfectly peeled skin close to 100% was obtained at 11% NaOH with a duty cycle value of 60% and 80%; and 13% NaOH with a duty cycle value of 80%. The calculation of the smallest percentage weight loss is 14.96% at 9% NaOH duty cycle 100% and the highest percentage weight loss is 35.89% at 13% NaOH 80% duty cycle.

Keywords: Vegetables; Concentrations; Thin Skins; Peeling

1. Introduction
One of the post-harvest processes in horticultural products and tubers before processing is stripping. Peeling is an integral part of food processing. Most agricultural crops have to be peeled to remove the product skin which is done in the early stages of food processing [1]. Indonesia is the world's 40th potato producer and Asia's 13th. The yield of Indonesian potatoes according to FAOstat [2] and The Indonesian Ministry of Agriculture [3] is 1.28 million tons, where potato consumption in Indonesia increases every year. Indonesian potato yields were 1,476 kg / capita / yr in 2014 and increased to 2,282 kg / capita / yr in 2018 [4].

Potatoes are one of the most widely used agricultural products for food, where they are mostly used after the skin is peeled. Mechanical peeling of fruit and vegetables is mostly done using abrasive tools or knives and blades [5], but this method wastes a lot of potato parts, and takes a long time. Fruit peelers are needed in fruit processing so that it can reduce the time needed to grate and peel the fruit [6]. Potato processing produces waste in the form of skin, pulp and waste. Sepelev and Galoburda [7] stated that industrial potato processing produces waste ranging from 15 to 40% of the initial mass,
depending on the method of stripping. According to Garcia and Barett [8], the stripping operation results in quite a large yield loss, so it is important to minimize yield loss while maintaining product quality through an ideal peeling method, one of the stripping methods is the lye peeling method. According to Caceres et al. [9] the peeling method of cubiu fruit by immersing it in NaOH boiling solution is better than manual peeling with a stainless-steel knife, NaOH also inhibits the browning process. The alkaline method is a method that can reduce the yield loss during the process of peeling fruits / vegetables and thin-skinned tubers. This method is used primarily to peel fruits, vegetables and tubers by soaking / immersing the product in an alkaline solution at high temperature (90-100 °C) [10]. In alkaline stripping, the alkaline solution dissolves the pectic and hemicellulose material in the cell wall by cleaving α - (1 → 4) bonds between individual galacturonic acid units. Pectin removal weakens the cellulose microfiber tissue and sheds the skin [11]. Alkali peel (NaOH) has been used extensively in peaches, tomatoes, kiwi, and potatoes [8, 10, 12], mangoes [13]. Caceres et al [9] cubiu (Solanum sessili fl orum Dunal), Di Matteo et al. [11] peeling hazelnuts using the Das and Barringer method [14], peeling tomatoes with KOH and NaOH solutions.

The purpose of this study was to design and fabrication a machine that can peel fruits and vegetables after the pretreatment process of soaking in hot NaOH. The way this machine works is by spraying pressurized water on the fruit soaked in hot NaOH solution.

2. Materials and Methods

2.1. Design Consideration

In the manufacture of potato skin peeling machines, the quality of potatoes as food and the durability of the fabrication materials are very concerned. To maintain the quality of the potato or the product to be peeled, the fabricated material must not contaminate but must have the ability to resist corrosion, because the material will be in constant contact with water. The materials chosen in fabrication for this machine construction are based on ease of fabrication, stability, rigidity, toughness and availability. Engineering properties such as water pressure for peeling potato skins, torsion moment, design power, screw torque, are considered in the design and fabrication of machines.

2.2. Design Analysis of the Machine Components

The main design analysis and calculations are carried out on the disk and shaft, and the water pressure.

2.2.1 Disc and shaft

The circular dish is where the potatoes will be peeled and the area can be calculated using the formula:

\[ A = \frac{1}{4} \pi d^2 \]  

(1)

While the shaft is made of solid iron measuring 8 mm and 150 mm in diameter and length, respectively. Torque on shaft thread (T) [15]:

\[ T = F \times \frac{D_m \times l + n_f \times D_m \times f}{\pi \times d_m \times f} \]

(2)

where, T is torque on the thread (Nm), Dm is diameter of thread pitch (m), F is force (N), f is coefficient of thread friction, and l is lead / pitch.

to be able to push the load (potato) on the plate and safety due to the failure of the torque, the torque produced by the motor must be greater than the torque acting on the thread. Based on these considerations, the value of the correction factor used is \( F_c = 2 \).

Power and Turning System Planning

Determine the ratio of gear (3 pieces) and tooth pulleys (2 pieces) on the rotary arm.

\[ \frac{N_1}{N_2} = \left( \frac{Z_2}{Z_1} \right) \times \left( \frac{Z_4}{Z_3} \right) \times \left( \frac{Z_6}{Z_5} \right) \]
The length of timing belt
\[ L_P = \frac{Z_5 + Z_6}{Z} + \frac{2C_P}{\epsilon_p} + \frac{[(Z_5 - Z_6)/6.28]^2}{\epsilon_P} \]

Determine the gear ratio on the disk pusher
\[ \frac{N_1}{N_2} = \frac{Z_2}{Z_1} \times \frac{Z_4}{Z_3} \times \frac{Z_6}{Z_5} \]

\[ N_2 = \frac{N_1}{(Z_2/Z_1) \times (Z_4/Z_3) \times (Z_6/Z_5)} \]

2.2.2 Determination and Regulation of Water Pressure

Determination and regulation of water pressure coming out of the nozzle is done using the pulse width modulation (PWM) method where PWM is a way to determine the electric voltage between the “High” and “Low” conditions. In this study, the voltage is adjusted by changing the duty cycle which is set using a potentiometer.

\[ PWM = \text{Duty Cycle} \times \text{Large PWM resolution} \]

- a) Duty Cycle 60%
  \[ PWM = 60\% \times 255 = 153 \]

- b) Duty Cycle 80%
  \[ PWM = 80\% \times 255 = 204 \]

- c) Duty Cycle 100%
  \[ PWM = 100\% \times 255 = 255 \]

Based on the three duty cycle values of the analog input setting values on the microcontroller, three variations of water pressure coming out of the nozzle will be generated, namely 60% (4.2038 Pa), 80% (5.6051 Pa), and 100% (7.0065 Pa) respectively for low levels, medium and high.

2.3 Machine Description

The machine consists of components that are assembled on top of a frame. The machine dimensions are 400 mm, 400 mm and 1000 mm long, width and height respectively.

2.3.1 The frame

The frame is made of corner iron 40 x 40 mm with a thickness of 3 mm. The frame has dimensions of length, width and height of 400 mm, 400 mm and 600 mm respectively.

2.3.2 Mounting tube

The tube holder has a function as a place for the tube to be attached to the frame and as a base for the peeler tube as well as a water reservoir before the water comes out through the outlet pipe. The tube holder itself consists of three parts that are welded together to form a single unit, such as the main plate that is square, the tube base plate that is tubular with a lid on one side, and an outlet pipe with dimensions of 400 x 400 mm and a hole in the middle with a diameter of 300 mm, the diameter of the base plate is 300 mm and is given a wall on the side of the circle as high as 43 mm.
2.3.3. Disc and Shaft
The dish on the peeler works to rotate the potatoes during the peeling process. This dish is made unstable so that the potatoes on it move. The dish is 294 mm in diameter and 2 mm thick. in the center of the disc is given a solid shaft with a diameter of 8 mm and a length of 150 mm which functions as a support for the disc.

2.3.4 Paring Tube
The peeler tube consists of three parts, namely the main tube, the top of the tube, and the peel output hole. the main tube has a height of 400 mm, a diameter of 300 mm, the top of the tube is half-spherical with an arc of 63 mm, and the output peel is made by perforating the wall of the peeler tube with dimensions of 140 x 100 mm with an output line with dimensions of 150 x 137 x 120 mm

2.4 Material Selection and Components Fabrication
The material for the machine support frame is chosen from angle iron 40x40 mm with a thickness of 3 mm. the tube holder and plate are selected stainless steel. 2 mm thickness. The axle is used to support the dish, choosing solid steel with a diameter of 8 mm and a length of 150 mm. The peeler tube is the main part of the 1.2mm thickness stainless steel plate. the water tank functions as a water reservoir for spraying and the water from the spray is selected by a plastic water tank on the market. The pressure regulator uses the Arduino uno ATmega 328 and a potesiometer serves to set the point in the analog signal

2.5. Construction Detailed Drawing
The isometric and orthographic projections of the peeling machine are shown in Figure 1.

2.6 Engine Testing
In collecting the stripping data, 9% NaOH solution was used as a Lye solution for pre-treatment. Data collection used three variations of water pressure based on the duty cycle value of 60%, 80%, and 100%. Spraying using a dual pump dc pump with one nozzle jet condition. The water pressure released by the pump is controlled by the pulse width modulation (PWM) method with a
potentiometer input signal setting 153 (60%), 204 (80%), and 255 (100%). The stripping process takes 3 minutes for each variation of water pressure. In pre-treatment with lye solution, potato tubers are soaked for 7 minutes with a NaOH temperature of 80°C.

Measurement of water pressure was carried out with 5 repetitions of the mass average value of 0.055 kg of water, while the surface area is 7.85 x 10^-3 with a value of r = 0.05 m and a potentiometer input of 255. Measurement using 100% duty cycle produces a pressure of 7.006369427 N / m2 (Pa).

3. Results and Discussion

3.1. Lye Peeling Machine of Potato

This study produced a small-scale lye peeling potato peeler with a capacity of 3 kg for a single process, with dimensions of length, width and height of 400 mm, 400 mm and 600 mm, respectively. The machine has a peeler tube and frame. The dimensions of the paring tube are 400 mm in height and 300 in diameter and the frame dimensions are 400 mm, 400 mm and 600 mm, respectively, length, width and height.

![Figure 2 Lye Peeling Machine for Small Capacity of Potato](image)

3.2. Physical properties of potato samples

In machine testing, a potato sample with a relatively uniform size was used in table 1.

| Sample | Major diameter (cm) (a) | Intermediate diameter (cm) (b) | Minor diameter (cm) (c) | Geometric mean Diameter (cm) (Dg) |
|--------|------------------------|-------------------------------|------------------------|----------------------------------|
| 1      | 3.690                  | 2.764                         | 2.550                  | 2.963                            |
| 2      | 3.430                  | 2.864                         | 2.260                  | 2.811                            |
| 3      | 3.648                  | 2.334                         | 1.780                  | 2.475                            |
| 4      | 3.740                  | 2.538                         | 2.210                  | 2.758                            |
| 5      | 3.224                  | 2.736                         | 1.880                  | 2.550                            |
| Average| 3.546                  | 2.6472                        | 2.136                  | 2.711                            |

The potatoes used in engine performance tests have relatively the same size.

3.3. Calculates the Percentage of Exfoliated Skin
The machine performance test was carried out by giving different NaOH treatments to potato samples at various water pressures and then looking at the peeled skin of the potato samples. The percentage of peeled skin in the potato sample can be seen in table 2.

| NaOH (%) | Duty Cycle (%) / Pressure (Pa) | Peeled Percentage (%) |
|----------|-------------------------------|-----------------------|
| 9        | 60/ 4,2038                    | 71.43                 |
|          | 80/ 5,6051                    | 57.14                 |
|          | 100/ 7,0065                   | 28.57                 |
| 11       | 60/ 4,2038                    | 100.00                |
|          | 80/ 5,6051                    | 100.00                |
|          | 100/ 7,0065                   | 57.14                 |
| 13       | 80/ 5,6051                    | 100.00                |
|          | 100/ 7,0065                   | 85.71                 |

In Table 2, it can be seen that for each treatment the concentration of NaOH given to peeled potatoes, the highest percentage of peeled potato skins is pressure 5.6051 Pa. This is because at high pressure (7.0065 Pa) the potatoes do not rotate smoothly so that there are parts of the potato that are not sprayed.

4. Conclusion
Lye peeling potato peeling machines have been designed, manufactured and tested. This machine can also be used for other thin-skinned horticultural products. This machine is designed to peel ± 3 kg of potato chips in one go. Engine performance is determined by water pressure. The results showed that the best pressure was 5.6051 Pa with 11% NaOH. This machine is easy to operate. Further improvements are suggested to add a water heater that is controlled according to the type of horticultural product.

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