# Design of a Potato Stick Cutting Machine: Improving Production Efficiency and Reducing Cutting Waste

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**Abstracts:** The designed of potato stick-cutting machine is a tool for cutting potatoes into long pieces. This machine is capable of cutting potatoes quickly and consistently. The aim of this research is to design a potato stick-cutting machine that can increase production efficiency and reduce cutting waste. The advantage of this machine lies in its ability to produce uniform potato pieces quickly compared to manual cutting. The design stages start with a field review, literature study, determining the design, calculating all machine components, making working drawings, component manufacturing process, assembling components, and finally testing the machine. This machine consists of a frame, knife, pully, v belt, knife body, and electric motor with a capacity of 214.2 Kg/hour. This potato stick cutting machine has dimensions of length x width x height respectively of 810 x 400 x 385 mm. By using a ½ HP motor as the driving force. The way this machine works is that the motor rotation is forwarded to the gearbox to reduce the rotation using a type A belt with a length of 32 inches and a pulley diameter of 3 inches and 4 inches. The operation of this potato stick-cutting machine is very simple inserting the peeled potatoes into the funnel in a horizontal position. Turn on the motor by pressing the start button, then the piston/pusher will push the potato towards the knife.

**Keywords:** Potatoes, Waste, Cutting Machines, Motors, Production, Waste Reduction

## 1. INTRODUCTION

Potatoes (Solanum tuberosum L) are a high-nutritional-value agricultural commodity that is an essential source of carbohydrates for human consumption [1]. Potatoes' high carbohydrate content makes them a nutritional option that can substitute other carbohydrate products including rice, corn, and wheat [2]. Potato as a staple food would be high in energy, vital elements (such as calcium, iron, salt, and selenium) [3,4], and a nutrient source to feed people sustainably [5,6]. Aside from nutritional benefits, potatoes offer strong market potential. Demand for processed potato goods has been driven by population increase, growing levels of education, rising income levels, and shifts in consumer preferences toward more practical food products [7]. This opens up numerous chances for the potato processing industry to develop a variety of processed goods with high economic value.

Potato sticks (french fries) are one of the most popular processed potato items. Despite rising demand for this product, potato stick raw material processing frequently employs conventional processes such as cutting with a hand knife. When cutting potatoes with a hand knife, the pieces are not uniform in size and thickness, and the operation takes a long time. Furthermore, this procedure necessitates a lot of labor and has a low work efficiency. In general, the traditional way of processing potato stick raw materials is a knife, still used in West Sumatra. As a result, creative solutions are required to improve manufacturing efficiency and generate high-quality potato stick products. Aside from that, any solution must consider environmental factors such as reducing waste of raw materials and energy. The development of an efficient and ecologically friendly stick-shaped potato-cutting instrument becomes critical in this situation [8-9].

The goal of this study is to create a stick-shaped potato-cutting machine capable of generating high-quality potato sticks at a low cost. The usage of this technology is envisaged to assist medium-sized entrepreneurs in the potato stick business in increasing the quality and quantity of their production while retaining production efficiency and sustainability. Aside from that, students must create this tool in order to accomplish their final assignment. As a result, the invention of this potato stick-cutting machine is an essential step toward ensuring the potato industry's long-term viability

## 2. Material and Methods

### 2.1. Calculation of the Main Component

The theoretical underpinning gathered from literature investigations was used to do the main component computations. The diameter of the driving and driven shafts, the intended power, the diameter of the driving and driven pulleys, the size of the driving and driven shafts, and so on are the primary components that are determined.

### 2.2. Designing a Machine Model

The design of the potato stick-cutting machine model is tailored to the machine's operation. The design process is divided into various stages, which include:

1. From the calculation results, determine the machine dimensions;
2. Drawing machine sketches;
3. Use drawing software (Catia/Solidworks) to convert machine sketch drawings to technical drawings.

### 2.3. Machine Production

This potato stick-cutting machine is constructed in phases based on the design drawings. The production process is as follows:

1. Production of main components;
2. Putting everything together;
3. Plating or painting.

### 2.4. Examine the machine's performance results

Inspections are performed to ensure that the outcomes of machine performance match the projected machine capacity.

### 2.5. Equipment and Supplies

This potato stick-cutting machine is constructed using standard machinery, tools, and measuring devices. The lathe is the machine used in the procedure. Machine for drilling. Machine for grinding. Welding equipment. Machine for cutting plates. Aside from it, the following tools were used in this research: a cutting saw. Etcher. Dropper. Hammer. Miser. Vise. Scissors for plates. Brush made of wire. Chisel for lathe. Measuring is required to modify the dimensions of the instrument manufactured to the calculation results. Sorog word will be utilized as the measurement instrument. A ruler made of steel. Meter. The protractor.

## 3. Results and Discussions

### 3.1. Calculation of Machine Elements

#### 3.1.1. Machine Capacity

Q = m.n

Where: m = 0.17 Kg, n = 21 rpm

Q = 0.17 Kg x 21 rpm

Q = 3.57 Kg/minute

Q = 214.2 Kg/hour

So, the engine capacity achieved through calculations is 214.2 Kg/hour

### 3.1.2. Shear Stress

We can calculate shear stress in a potato by performing the following experiment:

Steps for experimenting:

1. Prepare a balance, a potato stick-cutting tool, and 65-70 mm potatoes.
2. By pressing the knife downwards, cut the potatoes with a cutting knife on a balance.
3. When cutting potatoes, gather measurements and organize the data in Table 1.

**Table 1. Cutting Knife Experiment Results**

| Num | Ø Potato (mm) | Potatoes' cross-sectional area ($mm^2$) | Cutting Load (w) (Kg) | Cutting Style (w.g) (N) |
|---|---|---|---|---|
| 1 | 68.2 | $A = \frac{3{,}14}{4} \times 68.2^2 = 3651.22$ | 2.2 | 21.582 |
| 2 | 67.8 | $A = \frac{3.14}{4} \times 67.5^2 = 3576.65$ | 2 | 19.62 |
| 3 | 66.8 | $A = \frac{3.14}{4} \times 66.8^2 = 350285$ | 1.8 | 17.658 |
| Average | 67.5 | 3576.91 | 2 | 19.62 |

Based on the experimental data, the average cutting force for the largest potato with a diameter of 67.5 mm was calculated to be 19.62 N.

$$\tau g = \frac{Fc}{A}$$

Where: Fc = Cutting Style (N)

A = Potatoes' cross-sectional area ($mm^2$)

$$A = \pi r^2; A = 3.14 \text{ x } 33.752 \text{ mm}$$

$$\tau g = \frac{Fc}{A}$$

$$\tau g = \frac{19.62 \text{ N}}{3576.65 \text{ mm}^2}$$

$$\tau g = 0.00549 \text{ N/mm2}$$

### 3.1.3. Working Cutting Force

$$F = \tau g \text{ x } A$$

Where: F = Cutting Style (N)

$\tau g$ = Shear Stress ($N/mm^2$)

A = The surface area of the knife's cutting surface ($mm^2$)

**3.1.4. Determine Motor Power**

The following factors can be used to determine the motor power of a potato stick-cutting machine:

1. Power required to Cut Potato

P = $F.\omega.r$

Where: P = Power for cutting potatoes (watt)

F = Maximum cutting force of potatoes (N)

$\omega$ = The angular velocity (rad/s)

r = Disc radius (m)

$$\omega = \frac{2\pi n}{60}$$

$$\omega = \frac{2 \times 3.14 \times 21\, rpm}{60}$$

$$\omega = 2.198 \text{ rad/s}$$

P = F. ω. r

P = 140.54 × 2,198 $\frac{rad}{s} \times 0.055\, m$

P = 16.98 watt

2. Power to rotate the engine in the absence of a potato

F = (disk weight + piston rod weight + piston weight) x g

= (1.3 Kg + 0.3 Kg + 0.3 Kg) x 9.81 $m/s^2$

= 1.9 Kg x 9.81 $m/s^2$

= 18.639 N

P = F . ω . r

= 18.639 N x 2.198 rad/s x 0.055 m

= 2.25 watt

As a result, the total motor power needed to operate the potato stick-cutting machine is

P1 + P2 = 16.98 + 2.25 = 19.23 watt.

Required motor power (1 watt = 0.00134 Hp) (1 Hp = 745 watt)

Fc = Correction Factor (1.2)

Pd = Fc x Ptot

= 1.2 x 19.23 watt

= 25.78 watt

= 0.034 Hp (Motor used 0.5 Hp)

### 3.1.5. Motor torque

$$T = \frac{5250 \cdot P}{n}$$

Where: P = Motor power (watt)

n = Motor rotation (rpm)

$$T = \frac{5250 \times \frac{1}{2}}{1400}$$

T = 1.87 lb.ft = 2.44 Nm

### 3.1.6. Piston Road Calculation

The type of material used is ST 37

(Safety factor = v = 6)

$\sigma$max = 37 Kg/mm$^2$ x 9.81 m/s$^2$ = 362.97 N/mm$^2$

$$\sigma \text{ press} = \frac{\sigma \text{ press}}{v}$$

$$\sigma \text{ pres} = \frac{362.97 \text{ N/mm}^2}{6}$$

$$\sigma \text{ press} = 60.495 \text{ N/mm}^2$$

$$\sigma \text{ press} = \frac{F}{A}$$

$$60.495 \text{ N/mm}^2 = \frac{140.54 \text{ N}}{A}$$

$$A \text{ (planning)} = 2.32 \text{ mm}^2$$

$$A \text{ (actual)} = \pi r^2$$

$$A \text{ (actual)} = 3.14 \times 92$$

$$A\ (actual) = 254.34\ mm^2$$

$$\sigma\ actual = \frac{F}{A}$$

$$\sigma\ actual = \frac{140{,}54\ N}{254.34\ mm^2}$$

$$\sigma\ actual = 0.55\ N/mm^2$$

So, σ actual < σ press, this piston rod is then safe to use.

### 3.1.7. Piston Connecting Shaft Calculations

The type of material used is ST 37.

$$\sigma t = \frac{362.97\ N/mm^2}{6}$$

$$\sigma max = 37\ kg/mm^2 \times 9.81\ m/s^2$$

$$= 60.495\ N/mm^2$$

$$= 362.97\ N/mm^2$$

$$\tau g = 0.8 \times \sigma t$$

$$= 0.8 \times 60.495\ N/mm^2$$

$$= 48.39\ N/mm^2$$

$$\tau g = \frac{F}{2A}$$

$$48.39\ N/mm^2 = \frac{140.54\ N}{2\frac{\pi}{4} \cdot d^2}$$

$$d^2 = \sqrt{\frac{2 \times 140.54\ N}{3.14 \times 48.39\ N/mm^2}}$$

$$= \sqrt{\frac{281.08}{151.94\ /mm^2}}$$

$$= \sqrt{1.81\ mm^2}$$

$$= 1.35\ mm$$

$$\tau g\ (actual) = \frac{140.54\ N}{2\frac{\pi}{4} \cdot 16^2}$$

$$= 0.35\ N/mm^2$$

So, τg (actual) < τg, the shaft is then safe to use.

### 3.1.8. Bolt Calculation for Blade Holders

The type of material used is ST 37

$\sigma max = 37\ kg/mm^2 \times 9.81\ m/s^2$

$= 362.97\ N/mm^2$

$$\sigma t = \frac{362.97\ N/mm^2}{6}$$

$= 60.495\ N/mm^2$

$$A = \frac{\pi}{4} . db^2 . n$$

$$= \frac{\pi}{4} . db^2 . 8$$

$= \pi . db^2 . 2$

$$\tau g = \frac{F}{A}$$

$$60.495\ N/mm^2 = \frac{140.54\ N}{\pi . db^2 . 2}$$

$$db^2 = \sqrt{\frac{140.54\ N}{3.14 \times 60.495\ N/mm^2 \times 2}}$$

$= \sqrt{0.36}$

$= 0.6$ mm

Because the bolts used are M4, they are safe to use.

### 3.1.8. Pulley Calculation

The pulley calculations for the potato stick-cutting machine include the following:

1. Small Pulley (dp)

In this plan, the small pulley uses a 3-inch pulley. Because the small pulley is directly connected to the electric motor, the rotation that occurs is the same as the motor rotation, namely n = 1400 rpm.

2. Large pulley (Dp)

The assumed rotation for the potato stick-cutting machine is 21 rpm. Because the ratio of rotation from 1400 rpm to 21 rpm is too large, a speed reducer with a ratio of 1: 50 is used. So the rotation produced by the large pulley is 21 rpm x 50 = 1050 rpm.

$$\frac{n1}{n2} = \frac{Dp}{dp}$$

Where: n1 = 1400 rpm
n2 = 1050 rpm
dp = 3 inchi

$$\frac{1400\ rpm}{1050\ rpm} = \frac{Dp}{3\ inchi}$$

$$Dp = \frac{1400\ rpm \times 3\ inchi}{1050\ rpm} = 4\ inchi$$

### 3.1.9. Belt Planning

The belt planning for the potato stick-cutting machine includes the following:

1. Determine Belt Size

Because the motor power used is 0.5 Hp with a rotation of 1400 rpm, according to the table, type A belt size is selected.

Width = 12.5 mm

Thickness = 9 mm

Belt material = Rubber

Rubber density: 1.14 (gr/cm$^3$) [10]

Small pulley diameter = dp = 3" = 76.2 mm

Large pulley diameter = Dp = 4" = 101.6 mm

Belt Linear Speed (V)

$$V = \frac{\pi . dp . n1}{60 \times 1000}$$

Where: V = Belt speed (m/s)

dp = Motor pulley diameter (mm)

n1 = Motor Speed (rpm)

V = (3.14 x 76.2 mm x 1400 rpm)/(60 x 1000)

V = 5.582 m/s

2. Determine the Belt Length (L)

$$L = 2C + \frac{\pi}{2}(Dp + dp) + \frac{1}{4C}(Dp - dp)^2$$

Where: L = Belt length (mm)

C = Axis distance (mm)

Dp = Large pulley diameter (mm)

dp = Small pulley diameter (mm)

$$L = 2 \times 275 + \frac{3.14}{2}(101.6 + 76.2) + \frac{1}{4 \times 275}(101.6 - 76.2)^2$$

$= 550 + 1.57\ (177.8) + \frac{1}{1100}\ (645.16)$

= 550 + 269.146 + 0.58

= 819.726 mm

= 32 inchi

3. Distance from Motor Axis to Reducer

$$C = \frac{b \pm \sqrt{b^2 + 8(Dp - dp)^2}}{8}$$

Where: C = actual axle distance (mm)

b = 2L – 3.14 (Dp + dp) (mm)

= 2 × 819.726 – 3.14 (101.6 – 76.2)

= 1659.45 – 558.292

= 1101.158 mm

$$C = \frac{b \pm \sqrt{b^2 + 8(Dp - dp)^2}}{8}$$

$$= \frac{1101.158 + \sqrt{1212548.94 + 5161.28^2}}{8}$$

$$= \frac{1101.16 + 1103.49}{8}$$

= 275.58 mm

4. Contact Angle

$$\theta = 180^\circ - \frac{57(Dp - dp)}{C}$$

Where: θ = Contact angle (°)

C = Axis distance (mm)

Dp = Reducer pulley diameter (mm)

dp = Motor pulley diameter (mm)

$$\theta = 180^\circ - \frac{57(101.6 - 76.2)}{275.5} = 174.7^\circ$$

### 3.2. Potato Stick Cutting Machine Design Drawing

Based on the calculations above, the anticipated design of the potato stick-cutting machine is shown in Figure 1. The building characteristics of the potato stick-cutting machine are decided by the following factors:

1. Capacity of 214.2 kg/hour;

2. Electric motor with 12 HP power and 1400 rpm rotation;
3. Using a type A pulley with a driving pulley of three inches and a driven pulley of four inches. As a result, it produces a rotational speed of 1050 rpm;
4. When a WPA 50 speed reduction with a 1:50 ratio is used, the resulting rotation is as follows:

$N2 = N1: 50 = 1050: 50 = 21$ rpm

This potato stick-cutting machine measures 810 mm in length, 400 mm in width, and 385 mm in height.

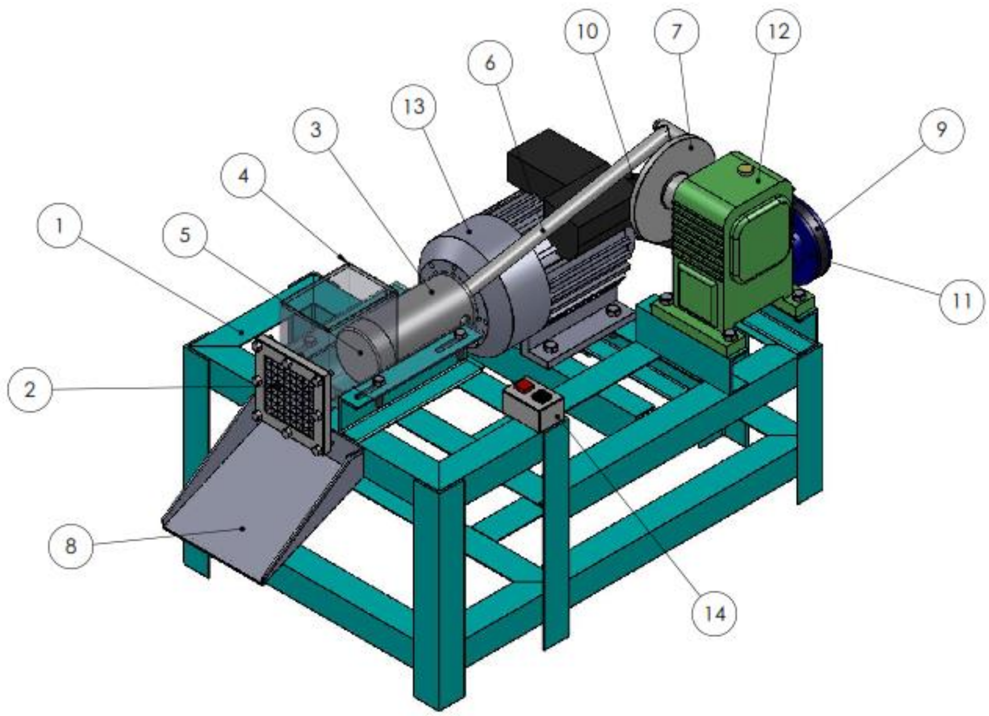


**Figure 1.** View of a Potato Stick Cutting Machine

**Table 2. Machine Components and Functions**

| No | Component | Machine Component Function |
|---|---|---|
| 1 | Component | Component support frame |
| 2 | Blade | Potato cutting knife |
| 3 | Piston tube | As a piston chamber |
| 4 | Input funnel (hopper) | Potato intake container |
| 5 | Supressor | Press the potato toward the blade |
| 6 | Piston puller | As a piston puller |
| 7 | Clutch | Connecting two shafts |
| 8 | Container | Holds directly the results of cutting potatoes |
| 9 | v-belt | Power supply |
| 10 | Pulley 1 | Transmits power |
| 11 | Pulley 2 | Transmits power |
| 12 | Gearbox | Reducing rotation |
| 13 | Electric motor | Driving force |
| 14 | Engine on off button | To turn the engine on and off |

### 3.1. How the Potato Stick Cutting Machine Works and the Process of Operation

This potato stick-cutting machine operates by inserting peeled and washed potatoes into the feeding chamber via the feeding funnel (hopper), which is attached to the cutting cylinder. The potatoes entering the cutting cylinder are positioned in this example so that they fall horizontally. The potato is cut by forcing it against a square blade with the help of a piston. The piston rod connects the piston to the crank disc. The crank disc is directly linked to the reducer output shaft. The reducer input shaft is connected to a pulley, and an electric motor with a belt (v-belt) is utilized as a power distributor to drive the pulley. A reducer is required to create a low rpm in order to lower the excessive speed of the electric motor. The knife blade will cut the strained potato, resulting in rectangular blocks emerging from the cutting region.

This potato stick cutting machine operates simply by introducing peeled potatoes into the funnel in a horizontal position. By hitting the contact button, you can start the motor, which will push the potato towards the knife. However, when using it, you must keep the following things in mind:

1. The potato stick-cutting machine must be properly prepared before use;
2. There is no substance that can damage the knife blade of the potato stick cutting machine while it is in operation;
3. The knife's sharpness must be maintained so that the cutting process produces better and more balanced outcomes;
4. If the potato to be cut has been forced against the knife, add the next potato immediately so that the first potato is completely pushed out;
5. After operating the potato stick cutting machine, clean the cylinder and knife.

**Figure 2**. Results of cutting potatoes into potato sticks

The test findings revealed that only 15-20% of the potatoes had edge damage, broken funds, or were crushed, with a capacity of 214.2 kg/hour. This device for cutting potatoes into potato sticks outperforms [11], with a capacity of 20.29 kg/hour and a success rate (excluding damaged potatoes) of 70.02%.

This potato stick-cutting machine is not only effective at cutting but also simple to use. Users simply place the peeled potatoes in the funnel horizontally and push the start button, and the machine will work swiftly and accurately. This simplicity boosts productivity while reducing the need for extensive training. This potato stick-cutting machine has a good impact on the environment and sustainability in addition to enhancing production efficiency. Additionally, it also contributes significantly to the generation of substantial quantities of waste, leading to significant environmental disposal challenges [12]. This machine, with its high production capacity and waste reduction capabilities, is a step toward a more sustainable food sector. The food business generates organic waste [13], and employing this technology will boost efficiency while decreasing waste [14-15].

## CONCLUSION

It is envisaged that the planning and construction of this machine will help potato stick entrepreneurs in general by making their jobs easier. A potato stick-cutting machine is a device used to chop potatoes into long segments. Not only that, but this machine produces even cutting results and cuts quickly. This machine has a capacity of 214.2 Kg/hour and is made up of a frame, knife, pulley, v belt, knife body, and electric motor. This potato stick-cutting machine measures 810 mm in length, 400 mm in width, and 385 mm in height. A 12 HP motor is used as the driving force. The gearbox will be connected to this motorcycle using a type A belt with a length of 32 inches and pulley diameters of 3 and 4 inches.

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