Designing small-medium scale groundnut (*Arachis hypogea* L.) shelling machine for local merchant in Tuban, East Java

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Abstract. In order to produce shelled groundnut, local merchants in Tuban are commonly use the manual methods by hand to shelled the groundnut which ineffective and inefficient. Therefore, the aim of this research is to design a groundnut shelling machine to accelerate the kernel production. There were three main stages that were conducted to achieve the result: designing, manufacturing and performance examination. Solidworks 2016 was used to design the 3D model of the machine before the manufacturing process in a workshop. The functional part of the machine consists of serrated roller and stator. While stator holds the groundnut, the roller rotates to break the pod by mechanical contact. Performance of the machine was then examined by varying the rotation speed of motor: SR 1, SR 2 and SR 3. One-way ANOVA perceived that SR 1 gave the significant fastest average operation (115.46 kg/h) \((p < 0.0001)\) followed by SR 3 (96.78 kg/h) and SR 3 (99.89 kg/h). Speed Rotation 1 also gave the lowest damaged kernel about 30.96% among all dim \((p < 0.05)\). Moreover, the machine gave more than 99% shelling efficiency and less than 0.5% losses. Further research must be conducted regarding varying lower rotation speed, moisture content, and different variety of groundnut.

1. Introduction

Groundnut (*Arachis hypogea* L.), one of the second important legume commodity in the world [1], is widely cultivated in the tropical area. In East Java, Tuban becomes the largest supplier which contributes around 20% of groundnut production on that province [2]. In terms of climatic requirements, groundnut can grows at temperature 20°C to 35°C and can be cultivated under limited soil moisture [3]; these make groundnut can survive in dry land and former paddy soil [4]. Moreover, the cultivation of groundnut can improves mechanical and chemical soil properties, renews soil fertility and reduces cereal crop diseases [5]. Therefore, because most part of Tuban is dry land, the local farmers prefer to plant groundnut beside paddy as the main commodity.

Small-medium merchant in Tuban usually sell the crops as the whole groundnut or kernel. Most of the kernel supplied to the market used as raw material for daily consumption (groundnut wheat, cookies, roasted nut), traditional food (pecel, bajigur, wedang ronde), and animal feed [6]. To do post-harvest handling for producing groundnut kernel, most of small-medium enterprises have to take two main processes: threshing and shelling. To separate the groundnut pod from the plant, threshing process can be done by using hand or mechanical equipment. However, many merchants prefer to use the manual method to shell the groundnut because there is no existing machine on Tuban region; they
use hand to tear down the groundnut pod and separate it with the kernel. However, this method is time consuming and ineffective. It needs more worker 5-10 times as much as manual threshing process [7]. Besides, if the enterprises want to increase shelling capacity, they have to hire many workers which can lower economic efficiency.

There are some shelling machines designs exist outside Tuban. Yet, the machines were design for specific types of groundnut. Some studies have been reported that by using the manual method, shelling process takes only 0.4-0.8 kg/hour while by using existing shelling machines, the capacity can greatly improve to 35 kg/hour [8, 9]. But, small capacity provided by existing machine could not handle high intensity of shelling process. Therefore, in order to tackle this challenge, this research focuses on designing functional part of groundnut shelling machine for small-medium scale merchant in order to accelerate the shelling process. In addition, machine performance would also be examined.

2. Material and Methods
2.1. Material
Thirty kilograms of groundnut (hypoma variety) were taken from The Research Center of Legume and Tuber (BALITKABI), Ministry of Agriculture is used to examine the performance of groundnut shelling machine. Initial moisture content of groundnut was varied from 7.89 to 8.53 % dry basis.

2.2. Designing process
The research was done as seen in the flowchart in Figure 1. To complete the designing process, three main processes are conducted: Concept design, manufacture and performance examination.

![Flowchart Diagram](image)

**Figure 1.** Flowchart diagram of research.

2.3. Concept design
Solidworks 2016 was used to design the 3D model of the machine. In this step, the functional part was defined first followed by conceptual of structural form. Some moving parts were mechanically simulated under the software to understand if the design was properly defined. The goal of this step is providing the blueprint of the functional part and structural design of the machine.

![Designs](image)

**Figure 2.** Initial design of groundnut shelling machine: (A) complete design and (B) breakdown part.
2.4. Manufacture
Capacity, motor power, form factor and materials of the machine were defined to obtain a good quality of machine before the manufacturing process. After that, all parts were assembled in the workshop. In this step the functional parts were tested whether it work well or not. A modification was done when some parts of the machine does not work properly. The output of this process was the prototype of the groundnut shelling machine.

2.5. Performance test
Shelling machine was examined by varying speed rotation using 3 different types of pulley: 2 dim, 2.5 dim, and 3 dim. Several parameter of the machine were determined such as shelling capacity, shelling efficiency, damage level, and losses to understand the actual performance of the machine. Shelling Capacity (SC) was then calculated by Equation 1 [10]; this parameter was calculated to study the work speed of the machine.

\[ SC = \frac{G_o}{t} \times 3600 \]  

Where:  
- \( SC \) = Shelling capacity (kg/h)  
- \( G_o \) = Total groundnut sample (kg)  
- \( t \) = time to shell (s)

Shelling efficiency was defined as how good the machine can break the groundnut pod, this parameter was calculated by Equation 2 [10]:

\[ \eta = 100 - \left( \frac{G_{us}}{K_o} \times 100 \right) \]  

Where:  
- \( \eta \) = Shelling efficiency (%)  
- \( G_{us} \) = Unshelled groundnut (g)  
- \( K_o \) = Total kernel (g)

Even though the machine can break the groundnut pod, there was still a high risk of mechanical damage to the kernel during the shelling process. So mechanical damage was also calculated by Equation 3 to know how much damaged-kernel produced by the machine:

\[ MD = \frac{K_d}{K_o} \times 100 \]  

Where:  
- \( MD \) = mechanical damage (%)  
- \( K_d \) = Damage kernel (g)  
- \( K_o \) = Total kernel (g)

When the machine was activated, there was a possibility where the groundnut was thrown off out of the machine which defined as losses. It was calculated by equation 4 [10]:

\[ L = \left( \frac{K_{tr}}{K_o} + \frac{G_{us}}{K_o} \right) \times 100 \]  

Where:  
- \( L \) = Losses (%)  
- \( K_{tr} \) = Thrown kernel (g)  
- \( K_o \) = Total kernel (g)  
- \( G_{us} \) = Unshelled groundnut (g)
All of the collected data performance was then analysed by one-way ANOVA using IBM SPSS Statistics 25 to perceive the effect of different dim to the performance.

3. Results and Discussion

3.1. Design of groundnut shelling machine

Groundnut shelling machine was manufactured from several primary components: hopper, serrated roller and stator cylinder, electrical motor, V-belt and pulley, and shaft (Figure 3). The functional parts were an important part in shelling mechanism to remove kernel inside groundnut pod [11]. Serrated roller and stator placed inside rotor and stator cylinder (Figure 4) were designed as functional part to crack the groundnut pods. The roller was made from a circular hollow iron plate then modified to have small half-circle-dot-pattern on the surface. The pattern was designed to provide force while breaking the groundnut pod. Meanwhile, stator would hold the movement to produce friction effect to the groundnut. The stator was made from several single iron bars formed into a half circle shape with a gap between the bars. These components were also useful to flow the cracked groundnut to the outlet.

![Figure 3. Groundnut shelling machine.](image)

**Figure 3.** Groundnut shelling machine.

![Figure 4.](image)

**Figure 4.** (A) Functional part of groundnut shelling machine, (B) serrated roller, and (C) stator.

The designed capacity of the machine was 3 kg for every batch process. As seen from the Figure 3, shelling process was started from the top of machine through the hopper and ended to the outlet. First,
electrical motor (0.5 HP; 1 phase) moved the shaft that connected to the roller. When groundnut was supplied to the hopper, it will hit the bar and cracked by the serrated roller. The result was cracked pods and kernel which went down to the outlet. Separating process between pods and kernel was conducted manually after pods and kernels out from output container. Drive pulley played a role to vary the speed rotation of roller. It adjusted the initial speed from motor to desired speed. The pulley was connected to stator pulley by using V-belt. Then it will transmit the speed by using a single shaft connected to the roller. All parts were place on an iron frame structure in one compact design.

3.2. Performance examination

The shelling machine was examined by adjusting speed rotation (SR) from constant rotation of electrical motor using 3 different size of drive pulley: 2 dim, 2.5 dim and 3 dim. From each pulley it provide SR 1 (237.63 ±0.33 RPM), SR 2 (290.06±5.98 RPM) and SR 3 (355.15±0.4 RPM). Every speed rotation was tested with 3 repetitions with for every repetition, 3 kg of groundnut were put on the hopper and the shelling product was then collected from 3 parts of the system: outlet of machine, stator, and outside system. From Table 1, the data were then calculated to get shelling capacity, shelling efficiency, mechanical damage, and losses.

| Parameter               | SR 1 (n = 3) | SR 2 (n = 3) | SR 3 (n = 3) | P     |
|-------------------------|--------------|--------------|--------------|-------|
| Shelling Capacity (kg/h)*** | 115.46 ± 5.09 | 96.79 ± 2.91 | 83.29 ± 0.31 | 0.0001 |
| Mechanical Damage (%)*   | 30.96 ± 4.04  | 43.93 ± 5.38 | 47.35 ± 4.28 | 0.011 |
| Shelling Efficiency (%)  | 99.92 ± 0.14  | 99.96 ± 0.04 | 99.89 ± 0.11 | 0.74  |
| Losses (%)               | 0.14 ± 0.11   | 0.06 ± 0.06  | 0.15 ± 0.12  | 0.48  |

*Significant at p < 0.05; *** Significant at p < 0.0001 (one-way ANOVA among all dim type)

3.2.1. Shelling capacity and mechanical damage

Shelling capacity was defined as how much groundnut was shelled in kilogram per hour (kg/h). Before measuring, groundnut was put into the hopper, and then it covered by a plastic lid to prevent the sample went out during the shelling process. Three different sizes of pulleys were examined in order to know the best rotation speed. The time was measured in the second start from the machine was
activated then 3 kg of groundnut were put on hopper until all samples were totally disappeared from the bottom of the hopper. The one-way ANOVA exhibit that speed rotation gave significant effect to shelling capacity ($p < 0.0001$). From Table 2, SR 1 gave the fastest operation (115.46 ± 5.09 kg/h) followed by SR 2 (96.78 ± 2.91 kg/h) and SR 3 (83.29 ± 0.31 kg/h). SR 1 could give high shelling capacity because the roller and stator simultaneously work properly to break groundnut. The roller supplied the groundnut into stator in the right quantity which fit to the gap between roller and stator. So the functional parts could manage the shelling process. On the other hand, when the speed rotation increased, the gap between stator and roller cannot handle a big amount of groundnut. As the sample was supplied, the flow increased as much as roller rotation speeds; this condition made the sample got an additional force which can worsen the shelling process. Therefore, it needs more time for the roller to break and flow the product to the outlet.

Not only lower shelling capacity, but the high speed rotation of roller could also make bigger physical defect to the kernel. From the examination (Table 1), when the shelling machine was operated, the higher speed of roller rotated the bigger mechanical damage of kernel occurred ($p < 0.011$). Table 1 showed an interesting fact that SR 1 gave the lowest average mechanical damage around 30.96 % while other gave 43.93% (SR 2) and 47.35% (SR 3). Comparing to other existing shelling machines, shelling capacity from this machine showed a better performance. The new design could greatly improve the shelling capacity up to 3.2 times as much as the previous model [8]. However, mechanical damage of the machine on this research was higher compared to others which could give damage level below 20% [8][9]. One factor that made this machine has higher mechanical damage was because of rotation speed. Unlike the machine from this research, the previous machine which also uses a rotation mechanism, they applied low speed rotation ranging from 52 RPM to 145 RPM.

A study reported that bulk density increase with the decrease of moisture content. Groundnut with moisture content 7.3% have a high bulk density rather than 28.1% [12]. So, in this research with the groundnut which had moisture content ranging from 7.8-8.5%; it contained high bulk density which affects the shelling process. A bulk product could increase the cracking effect while shelling. Right before groundnut shelled by roller, there was an extra force from the sample on the hopper, this could provide more mechanical damage to the kernel.

3.2.2. Shelling efficiency and losses

It is well informed that the machine gave high shelling efficiency which above 99% (Table 2). This means that almost all groundnuts could be cracked by the machine. Comparing to the other designs, shelling efficiency of the machine was improved while the others ranging from 83% - 98.9% [8, 9, 13]. Moisture content of groundnut plays a role for shelling efficiency. A study reported that the smoother groundnut surface the lower coefficient of friction which lower breaking effect from functional parts of the machine [14]. When groundnut was in a high level of moisture content, the outer skin became soft and loamy which hard to be cracked. However, in low moisture content, the groundnut would be firm; this condition makes it easy to be cracked by mechanical force.

The moisture content of groundnut also influences the losses during the shelling process. When groundnut hit by mechanical contact, lower moisture content of groundnut will release more dust from the outer skin. Nevertheless, according to Table 1, there is no significant difference from speed rotation provided by 3 different speed rotations ($p = 0.48$); all types of pulley gives low losses below 0.5%.

4. Conclusion

Designing and performance test of groundnut shelling machine was carried out. Serrated roller and stator were designed as a functional part to crack the groundnut pod. The machine could operate up to 115.46 kg/h of work capacity with the percentage of the shelled nut of 30.96% using SR 1. The machine provides good shelling efficiency which above 99% and a low percentage of losses below
0.5%. Overall, SR 1 pulley gave the best performance among others. However, further research must be conducted regarding speed operation of the serrated roller in low RPM. Moreover, varying moisture content and different variety of groundnut have also to be observed to understand the scope operation of the shelling machine.

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