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# Redesign of coconut grater blades to minimize coconut milk reduction using the reverse engineering method

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## ABSTRACT

**Background:** Indonesia is one of the countries with the highest coconut production and productivity levels in the world. The use of coconut in Indonesia is often employed in the production of coconut milk, both in households, small industries, and large industries. To produce coconut milk, grated coconut is required. Grated coconut is obtained from coconuts that have been grated using a grating machine. This study used a coconut grating machine available at Telkom University, which produces grated coconut with a significant reduction in coconut milk yield, namely 56.25% of the previous grated coconut weight. The study aims to reduce the reduction in coconut milk yield to achieve a more optimal result by using the Reverse Engineering method with the assistance of a 3D Scanner. **Methods**: This study employed a reverse engineering approach comprising systematic stages of field observation, data acquisition, 3D scanning, and component redesign to develop an optimized coconut grater. The redesigned model was then tested and compared with the existing grater to evaluate improvements in grating performance and coconut milk extraction efficiency. **Findings:** The 3D Scanner results were then processed using Solid Edge software, which functions to display the 3D design that can be analyzed and modified according to the research objectives. Once the necessary modifications were identified, the next step was the redesign process. The redesign process was carried out using Autodesk Fusion to redesign the new or proposed grater. A reduction of 28.33% was obtained, with a difference of 27.92% from the previous grater reduction. With a reduction of 27.92%, coconut milk production became more optimal compared to the previous results. **Conclusion**: This study concluded that redesigning the coconut greater using the Reverse Engineering method effectively reduced the coconut milk reduction rate from 56.25% to 28.33%, resulting in a 27.92% improvement in extraction efficiency. **Novelty/Originality of this article:** This study introduces an improved coconut greater design developed through the Reverse Engineering method using 3D scanning and CAD software, resulting in optimized grater tooth dimensions that significantly reduce coconut milk yield loss and enhance extraction efficiency.

**KEYWORDS**: 3D scanner; coconut; reverse engineering; solid edge; tooth grater.

## 1. Introduction

Coconut (*Cocos nucifera L.*) is a tropical plant that grows well in coastal areas up to an altitude of 600 meters above sea level (Sutrisno et al., 2023). As a typical tropical crop, coconuts are widely distributed throughout Indonesia, making the country one of the world's largest coconut producers. Global coconut production has increased by an average of 0.15% over the past decade, rising from 58.39 million tons in 2011 to 61.52 million tons in 2020, with average productivity growing by 0.46% per year (Center for Agricultural Data and Information Systems, 2022). Indonesia ranks first as the world's largest coconut

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producer with a total production of 17.19 million tons, followed by the Philippines and India. Overall, six major coconut-producing countries—Indonesia, the Philippines, India, Brazil, Sri Lanka, and Vietnam—account for approximately 85.01% of global coconut production (Center for Agricultural Data and Information Systems, 2022).

Most of Indonesia's coconut production is used for domestic consumption, both by households and processing industries (Center for Agricultural Data and Information Systems, 2022). The most widely used coconut derivative product is coconut milk, which is extracted from grated mature coconut meat with or without added water (Gefalro et al., 2023a). Demand for coconut milk continues to grow, driven by global trends toward plant-based products and Indonesia's increasing population (Lerebulana et al., 2018). In 2022, Indonesia exported 97,074 tons of coconut milk valued at USD 156 million, while by July 2023, exports had reached USD 116.8 million—an increase of more than 90% compared to the same period in the previous year (Ministry of Foreign Affairs of the Republic of Indonesia, 2024). This growing demand for coconut milk has directly increased the need for grated coconut, both in household-scale and medium-scale industries (Nasution et al., 2022).

The production process of coconut milk involves several stages, including peeling, grating, and squeezing the coconut (Hadi et al., 2022). In this process, the coconut grating machine plays a crucial role in producing optimal grated coconut before the squeezing stage (Manane et al., 2021). Various types of coconut grating machines are now available on the market with different power capacities, one of which is a 1 HP grater machine used at Telkom University. However, testing results indicate that this machine produces a relatively high reduction rate of 56.25% from 4 kg of grated coconut meat—higher than the typical reduction range in the market, which is between 33.33% and 47.5% (Khairunnisa & Aisyah, 2021; Winneke, 2018). This finding suggests that the existing machine is not yet optimal in extracting coconut milk from grated coconut.

The high reduction rate in coconut milk yield highlights the need to optimize the design of the grater teeth, as the size and shape of the grated coconut significantly affect extraction efficiency (Riyadi & Mahmudi, 2021). Currently, there is no standardized design or dimension for grater teeth that ensures the most effective coconut milk extraction, but two common types widely used in the market are coarse and fine greater blades. Based on observation and direct testing of the existing grater machine at Telkom University, the results showed that from a total of 10 coconuts with 4 kg of coconut meat, the extracted coconut milk weighed 1.75 kg, resulting in a reduction rate of 56.25%. Based on the discussion above, this study addresses the central problem of designing a coconut grater blade capable of reducing the rate of coconut milk loss during extraction. Accordingly, the objective of this research is to develop a blade design that minimizes milk loss and enhances extraction efficiency through the application of the reverse engineering method.

## 2. Methods

This research consists of four main stages which is, the preliminary stage, the data collection stage, the data processing stage, and the analysis and conclusion stage. Each stage is systematically arranged to produce a more optimal coconut grater design. The initial stage focuses on problem identification and theoretical foundation gathering, while the subsequent stages emphasize observation, technical analysis, and redesign through a reverse engineering approach.

In the initial stage, observations and analyses were conducted on the coconut grating machine and its grating component through field studies and literature reviews. The field study aimed to identify problems related to the coconut grater by directly examining the existing coconut grating machine located in the Telkom University Laboratory, as well as reviewing the necessary components based on the existing grater design. Meanwhile, the literature review was carried out by collecting references from previous studies discussing the shape, size, position, spacing, and arrangement of coconut grater teeth, along with supporting references regarding the 3D scanning process relevant to this research. The data obtained from both studies were compiled to formulate the research problem; how to create a coconut grater design that can reduce coconut milk loss for more optimal results, considering that the existing grater experiences more than a 50% reduction from the total weight of ungrated coconut. Based on this problem formulation, the objective of this study is to redesign the coconut grater on the grating machine using the reverse engineering method to achieve more optimal grated coconut and coconut milk results (Otto & Wood, 1998). Next, the data collection stage was conducted through field observations to obtain important information about the actual condition of the coconut grating machine. The collected data included technical aspects of the existing machine, such as grating performance, coconut milk extraction efficiency, and the characteristics of machine components. These data then served as the basis for the following analysis stage, which aimed to develop a redesigned coconut grater capable of improving productivity and minimizing coconut milk loss.

Field observations were conducted on various aspects related to the coconut grating machine to identify and obtain important information regarding the current condition of the machine in use. The data obtained from these observations were then analyzed to support the subsequent stages of the research process. The collected research data included the coconut grating process flow, the condition of the machine and grated coconut, dimensional measurements, as well as the weight of the grated coconut and extracted coconut milk—all of which were obtained through direct observation in the field.

Next, in the data processing stage, the researcher designed a proposed grater model for the coconut grating machine, which is expected to produce coconut milk more optimally compared to the previous design. At this stage, a 3D scanner was used to support the reverse engineering process, where the scanning results produced a 3D model of the existing product. This 3D design served to facilitate the redesign process (Kantaros et al., 2023; Lee et al., 2014). With the existing 3D model, the researcher was able to extract design information as needed. The 3D product design also allowed for analysis of the parts that required improvement in accordance with the research objective—reducing milk loss and optimizing coconut milk yield. By using a 3D scanner, the data processing became more efficient, eliminating the need to recreate the entire existing 3D design from scratch. Subsequently, a redesign of the object was carried out to achieve the desired research outcome. The design process was also adjusted based on the data obtained from measurements and performance tests of the existing coconut grater.

At this stage, testing was carried out on the proposed design that had been developed. The experiment included testing the grated coconut results and the extracted coconut milk. After obtaining the test results, a comparison was made between the existing grater and the proposed grater. Finally, conclusions were drawn from the testing results, along with an analysis of the factors causing the differences in performance between the existing and proposed graters.

In the data collection stage, observations and field studies were conducted on various aspects related to the existing coconut grating machine, including the grating process flow, grater dimensions, and the resulting grated coconut and coconut milk. The initial stage of the reverse engineering method focused on data collection through direct observation of the existing coconut grating machine to obtain a comprehensive understanding of the machine's performance and actual condition. Observation, also known as field observation, is an activity that involves focusing attention on an object using all senses, making it a data collection technique conducted directly while recording all observed aspects (Prawiyogi et al., 2021). This observation stage aimed to understand real conditions in the field, identify problems found in the previous coconut grater, and gain an in-depth understanding of the grating characteristics of the existing coconut grating machine. Data regarding the coconut grating process flow were obtained through direct field observations, complemented by supporting references gathered from various previously collected sources.

The data processing stage in this research began with the scanning of the product to be reverse-engineered using a 3D scanner. This stage was followed by processing the scan data, redesigning the component, and conducting the manufacturing process until a final improved product design was obtained. The tool used was a HandySCAN BLACK 3D scanner, a portable optical-based handheld scanner equipped with a special grip for ease of use. This device functions to scan component surfaces and generate three-dimensional representations in the form of point clouds, and it can be used flexibly in various locations (Mandarani et al., 2021). Before use, the device must be connected to the VXelements application installed on a computer or laptop. The first step was calibration, which adjusts the camera to ensure accurate scan results that match the object's actual dimensions. The camera is used as part of the preparation stage for creating a 3D model, while calibration ensures the accuracy of the generated model (Azlan et al., 2020; Nurcahyo & Djurdjani, 2021; Srivastava & Kawakami, 2023; Yu et al., 2020). This process includes preparing a flat and stable area with even lighting and connecting the scanner to the computer. Calibration is performed using a patterned board as a reference target. After calibration, markers or stickers were attached to each side of the object to help the scanner read the product's surface comprehensively. The next stage was scanning all parts of the tool, producing digital data in the form of a point cloud, which was then processed into a surface model (Finishing of Point Cloud). The scan data were saved in .stl format and processed using Solid Edge software to generate a CAD model that accurately represents the real object (Gumilar et al., 2022; Salehi & Wang, 2019; Tickoo, 2020). The scanning results showed certain accuracy limitations in fine details, such as the shape and size of the grater teeth. Therefore, improvements were made to the scan results using the modified surface and extract surface features. The final step was surface smoothing, aimed at refining and cleaning up the model's surface using the smooth mesh feature. This stage produced a smoother shape that closely resembled the existing product. The refined .stl file was then used as the foundation for the product redesign stage in Autodesk Fusion, resulting in a new model with improved accuracy and efficiency.

The redesign process was carried out using Autodesk Fusion software, with the design results from Solid Edge serving as the main reference for modifying the existing product (Autodesk, 2024). At this stage, only the surface geometry from the Solid Edge output was used, as the previous 3D scanner data lacked sufficient accuracy in capturing detailed shapes and dimensions. Therefore, dimensional adjustments were made based on actual measurements taken with a micrometer. The grater was redesigned with an inner cylinder size adjusted to fit the existing coconut grating machine, as shown in the redesigned grater cylinder model. To improve grating capacity, attention was focused on the characteristics of the grater teeth, since the shape, diameter, height, and arrangement pattern of the teeth, as well as the operator's skill, significantly influence the grating capacity (Darma et al., 2020). Observations of the existing grater showed specifications of 2 mm tooth height, 2 mm width, 5 mm spacing between teeth, a cylindrical shape, and a dual-chamber arrangement pattern. Modifications were made to produce a finer grating texture, which would optimize the coconut milk extraction process. According to references by Riyadi & Mahmudi (2021) and Ramadhan & Fauzi (2022), smaller and more closely spaced teeth can produce finer and more efficient grating results. Based on this comparison, the new proposed grater specifications were determined as follows: 1.5 mm tooth height, 2.5 mm tooth width, 3.5 mm spacing between teeth, cylindrical shape, and a full-space arrangement pattern. These changes include reducing the tooth height to produce finer shavings, increasing the tooth width to achieve denser grated coconut, and decreasing the spacing between teeth to increase the number of cuts per rotation and reduce material loss from clogging. The modifications were then developed into 3D and 2D designs using Autodesk Fusion, resulting in a redesigned grater cylinder model that enhances the quality and efficiency of the coconut grating process (Mitra, 2016).

The manufacturing process of the coconut grater was carried out manually using a method of individually carving each grater tooth. The first step was sketching, which involved drawing guide lines on the surface of the grater cylinder to ensure that the grater teeth were aligned and straight according to the planned design (Mudzakir et al., 2017). After completing the sketch, the next step was selecting the carving tool used to shape the grater teeth. The selection of this tool was adjusted to the desired tooth dimensions, as the length and shape of the grater teeth could be controlled by modifying the size of the carving tool (Riyadi & Mahmudi, 2021). The final stage was the carving process, performed by following the sketched pattern to ensure that each carved section was precise and consistent with the design. This process required a high level of precision, as each grater tooth had to be carved manually one by one to ensure uniformity in shape and spacing. The result of this series of processes was a coconut grater with tooth characteristics that matched the design specifications, expected to improve the efficiency of the grating process and produce finer, more uniform grated coconut for optimal coconut milk extraction.

Fig. 1. Finishing project

The finishing stage was carried out after the manufacturing process to ensure that the final product conformed to the proposed design. At this stage, the grater surface was cleaned and refined to remove any remaining sharp material or carving defects. The finishing process also aimed to verify that the product's dimensions and specifications matched the design, including a total weight of 2 kg, a greater cylinder length of 15.5 cm, a tooth height of 1.5 mm, a tooth width of 2.5 mm, and a spacing of 3.5 mm between teeth. With these specifications, the proposed product is expected to produce finer coconut shavings and support a more efficient and optimal coconut milk extraction process.

## 3. Results and Discussion

### *3.1 Verification and validation*

The interpretation of the table shows that the validation process for the coconut grater design was carried out thoroughly, taking into account performance improvements, user requirements, and compliance with technical standards. Validation not only focused on functional aspects such as increasing grating results and reducing coconut milk loss, but also included re-engineering the previous design to produce a more efficient shape and dimensions for the grating teeth. This approach reflects a systematic effort to ensure that the new design has higher reliability and is able to optimally meet user demands through repeated testing, observation, and technical evaluation.

Table 1. Validation category

| Validation Category | Validation Target | Fulfillment |
|---|---|---|
| Performance Target Improvement of Coconut Grater Design | The previous grater design used as a reference was improved into the proposed product design. | Conducted observation and testing to produce the latest design. |
| Stakeholder Requirement Reduced Coconut Milk Loss Reference Standard | The proposed grater produces coconut milk more optimally than the existing grater. | Re-testing the proposed grater to obtain validation results related to coconut milk optimization. |

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| | | |
|---|---|---|
| Grating Teeth Dimensions | The proposed grater was designed with grating teeth dimensions that differ from the previous design. | Conducted reverse engineering and design processes. |

The testing was carried out using five grated coconuts without shells and five grated coconuts with shells, along with the addition of a total of 500 ml of water to facilitate the extraction of coconut milk.

Table 2. Additional weight data

| No | Name | Weight |
|---|---|---|
| 1 | Red Container | 0.1 kg |
| 2 | White Container | 0.1 kg |
| 3 | Rice Cooker Container | 0.3 kg |

*3.1.1 Grating results of the new grater*

In the Table 3 below, two types of coconuts were tested: coconuts with shells and coconuts without shells. The coconut with shell weighed 1.6 kg, and after grating, the grated result was 1.5 kg. The coconut without shell weighed 1.4 kg, and after grating, the grated result was 1.3 kg. In total, the combined weight of the 10 coconuts (flesh) was 3 kg. From this 3 kg, the total grated coconut obtained was 2.8 kg, indicating a reduction of 6.66% from the coconut's initial weight before grating.

Table 3. Grating results of the proposed grater

| No | Type of Coconut | Weight of 5 Coconuts (Without Water/kg) | Grated Result (kg) | Image |
|---|---|---|---|---|
| 1 | Grated coconut with shell |  1.7-0.1 = 1.6 kg | 1.6 – 0.1 (Red Container) = 1.5 kg |  |
| 2 | Grated coconut without shell |  1.4 kg | 1.9 – 0.6 (Rice Cooker Container) = 1.3 kg |  |
| Total weight of grated results (10 coconuts) | | 3 kg | 2.80 kg | 6.66 % (Reduction) |

*3.1.2 Coconut milk yield from the new grater*

In the Table 4 below, two types of coconuts were tested: coconuts with shells and coconuts without shells. The grated coconut with shell weighed 1.5 kg, and after being squeezed, produced 1.35 kg of coconut milk. The grated coconut without shell weighed 1.3 kg, and after being squeezed, produced 0.80 kg of coconut milk. In total, the combined weight of the 10 grated coconuts was 2.80 kg. From this amount, 2.15 kg of coconut milk was obtained, resulting in a reduction of 23.21% from the grated coconut's weight before squeezing.

Table 4. Proposed coconut grating results

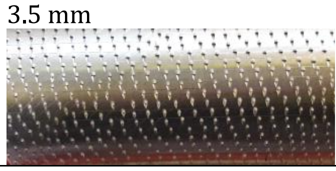
| No | Type of coconut | Grated Result (kg) | Coconut Milk Result (kg) | Image |
|---|---|---|---|---|
| 1 | Grated coconut with shell | 1.6 – 0.1 (Red Container) = 1.5 kg | 1.8 – 0.45 (Bucket Weight) = 1.35 kg |  |
| 2 | Grated cococnut without shell | 1.9 – 0.6 (Rice Cooker Container Weight) = 1.3 kg | 0.9 – 0.1 (Bucket Weight) = 0.8 kg |  |
| Total coconut milk from 10 coconuts | | 2.80 kg | 2.15 kg | 23.21% (Reduction) |

### *3.2 Analysis sesults*

#### *3.2.1 Dimension comparison*

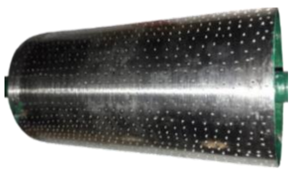
In the results analysis, a comparison was made between the specifications or dimensions of the existing grater and the proposed design, which had undergone the reverse engineering process, as well as a comparison of the testing results. The following table presents the comparison of specifications and test results between the existing grater, the proposed grater, and those available on the market.

Table 5. Dimension comparison

| Description | Existing Grater | Proposed Grater |
|---|---|---|
| Photo of grater |  |  |
| Weight | 4 kg | 2 kg |
| Diameter | 16 cm | 15.5 cm |
| Tooth Height | 2 mm | 1.5 mm |
| Tooth Width | 2 mm | 2.5 mm |
| Tooth Spacing | 5 mm | 3.5 mm |
| Photo of Teeth |  |  |

There was a change in the overall weight, which was reduced from 4 kg to 2 kg, making the grater lighter than before. Additionally, the tooth dimensions were modified — the tooth height was reduced by 0.5 mm, the tooth width was increased by 0.5 mm, and the spacing between teeth became narrower. These changes resulted in a greater number of shorter and denser grater teeth, producing finer and smaller coconut shreds compared to the previous design. Subsequently, the proposed grater was compared with other coconut graters available on the market.

Table 6. Comparison with existing market graters

| Description | Proposed Grater | Grater in market | |
|---|---|---|---|
| | | Large grater | Small Grater |
| Photo of grater |  |  |  |
| Weight | 2 kg | 1.3 kg | 0.3 kg |
| Diameter | 15.5 cm | 10 cm | 5 cm |
| Tooth height | 1.5 mm | 1 mm | 0.8 mm |
| Tooth width | 2.5 mm | 0.6 mm | 0.7 mm |
| Tooth Spacing | 3.5 mm | 6.7 mm | 3 mm |
| Photo of tooth |  |  |  |

Based on Table 6, the proposed grater has a greater overall weight compared to the other graters. This is influenced by the material used and the density within the grater cavity. It can also be observed that the large market grater has wider tooth spacing than the proposed grater. Moreover, the groove pattern differs — the proposed grater features diagonal grooves, while both the large and small market graters have straight grooves running from one end of the cylinder to the other.

### *3.2.2 Difference factors between existing and proposed grating results*

In the Table 7 below, there are five dimensional differences between the existing and proposed graters—namely in weight, diameter, tooth height, tooth width, and tooth spacing. Based on the testing process conducted, the size and configuration of the grater teeth significantly influence both the texture of the grated coconut and the resulting coconut milk yield. The following section presents the differences in grated results and coconut milk output as affected by the grater tooth design.

From Table 7, it can be seen that the grated result produced by the existing grater has a slightly coarser texture compared to the proposed grater, which produces a finer texture. This indicates that the size and dimensions of the grater teeth significantly affect the texture of the grated coconut. The thickness of the ungrated coconut meat is thinner when using the existing grater compared to the slightly thicker residue produced by the proposed grater.

This factor is influenced by the size and dimensions of the greater teeth; larger teeth can shred more coconut meat, resulting in a thinner leftover layer. Additionally, the smaller cylinder diameter of the proposed grater—5 mm smaller than the existing grater—also affects the thickness of the remaining coconut meat.

Table 7. Comparison results between existing and proposed graters

| No | Differentiating Factor | Existing Grater | Proposed Grater |
|---|---|---|---|
| 1 | Fineness |  |  |
| 2 | Thickness of ungrated coconut meat |  |  |
| | |  |  |

A smaller cylinder diameter increases the distance between the grater cylinder and the machine wall. This difference in spacing affects the grating results; grated coconut meat that matches the gap between the cylinder and the machine wall can enter the machine's chute more quickly and easily, but may not be grated optimally. Based on this analysis, there are two main factors influencing both the grated coconut and coconut milk yield: the size of the grater teeth and the cylinder dimensions (distance between the cylinder and the machine wall).

Fig. 2. Comparison of coconut grater designs showing the effect of teeth size and cylinder diameter on coconut meat residue

### 3.2.3 Comparison of testing results

Based on the data in the Table 8 below, the existing grater produced coconut milk with a reduction of 2.25 kg $(2.05 + 1.95) - (1.05 + 0.7)$, equivalent to 56.25% of the total weight of 10 coconuts (4 kg). In contrast, the proposed grater resulted in a reduction of 0.85 kg $(1.6 + 1.4) - (1.35 + 0.8)$, equivalent to 28.33% of the total 10 coconuts (3 kg). Thus, there is a difference of 27.92% in reduction between the existing and proposed graters, with the proposed grater showing 27.92% less reduction compared to the existing one.

Table 8. Comparison of existing and proposed grater results

| Type of coconut | Description | Existing grater | Proposed grater |
|---|---|---|---|
| Coconut with shell | Coconut weight | 2.05 kg | 1.6 kg |
| | Grated coconut | 1.95 kg | 1.5 kg |
| | Grating Reduction | 0.1 kg | 0.1 kg |
| | Coconut Milk Yield | 1.05 kg | 1.35 kg |
| | Total Reduction | 0.9 kg (1.95-1.05) | 0.15 kg (1.5-1.35) |
| Coconut without shell | Coconut weight | 1.95 kg | 1.4 kg |
| | Grated coconut | 1.75 kg | 1.3 kg |
| | Grating Reduction | 0.,2 kg | 0.1 kg |
| | Coconut Milk Yield | 0.7 kg | 0.8 kg |
| | Total Reduction | 1.05 kg (1.75-0.7) | 0.5 kg (1.3-0.8) |

### 3.3 Discusion

Coconut (*Cocos nucifera L.*) is a plant with high economic and social value in Indonesia—not only because of its abundant production but also because every part of the plant can be utilized for various human needs. It is often referred to as the "tree of life" since almost every part, from the roots to the leaves, holds significant economic benefits (Gefalro et al., 2023). According to Prades et al. (2016), the coconut belongs to the Arecaceae family and grows well in tropical regions, especially in coastal areas up to 600 meters above sea level. A coconut fruit consists of several layers: the outer skin (exocarp), the husk (mesocarp), the shell (endocarp), the brown skin (testa), the white flesh (endosperm), and the coconut water. The coconuts reach full size at the age of 9–10 months, weighing about 3–4 kilograms, with a flesh thickness of 8–10 millimeters. The composition of a mature coconut consists of approximately 35% fiber (husk), 12% shell, 28% flesh, and 25% coconut water. The flesh is the primary part used in food processing—mainly for producing coconut milk, oil, and flour. The chemical composition of the coconut flesh varies depending on its maturity level; young coconuts contain more water and less fat, while mature coconuts have higher oil content, making them ideal for coconut milk and oil production.

In the coconut milk production process, the grating stage plays a crucial role. Grating serves to increase the surface area of the coconut flesh, allowing a more efficient squeezing process and maximizing the milk yield (Hadi et al., 2022). Modern coconut grating machines are designed to replace the traditional manual grating method, which relies on human effort and is limited in speed and consistency. The grater functions to produce fine coconut flakes ready for squeezing. The main components of a coconut grater include a motor, shaft, frame, and a grating cylinder equipped with sharp teeth on its surface. Several factors affect the quality of grated coconut, such as the shape, height, width, spacing, and arrangement pattern of the teeth (Darma et al., 2020). Graters with shorter and denser teeth produce finer flakes, while taller teeth produce coarser shreds. Therefore, optimizing the design of the grater teeth is essential to achieve the ideal texture and improve coconut milk extraction efficiency.

The application of the reverse engineering method provides an effective approach for redesigning components of the coconut grating machine. According to Berger et al. (2016), reverse engineering is a process of reconstructing or redesigning an existing product by analyzing its form, structure, and function using digital technology (Belgiu, G., & Cărăușu, 2018). The process begins with 3D scanning of the existing product, followed by converting the scan data into a digital model using Computer-Aided Design (CAD) software. In this study, the reverse engineering approach was applied to analyze and redesign the coconut grater cylinder to enhance grating efficiency. The scanning process was carried out using a Handyscan Black, an optical-based handheld 3D scanner that captures three-dimensional point cloud data from the object's surface (Ghahremani et al., 2015; Haleem et al., 2022). The scan data were then processed using Solid Edge to generate an existing CAD model (Gumilar et al., 2022), which was subsequently modified in Autodesk Fusion to adjust dimensions and improve performance.

The quality of the scanning results greatly depends on calibration and scanning conditions (Helle & Lemu, 2021; Javaid et al., 2021; Yao, 2005; Zhaohui Geng, 2017). Situmorang (2019) emphasized that camera calibration must be performed before scanning to ensure the accuracy of the 3D model, while Nurcahyo & Djurdjani (2021) noted that stable lighting and proper object positioning also affect the results. After scanning, a surface smoothing process is carried out to refine the digital model and eliminate surface irregularities. Through these steps, a precise CAD model is obtained, serving as a reference for the redesign of the coconut grater component.

Observations of the existing coconut grating machine revealed that the grater tooth dimensions were not yet optimal. The existing grater features teeth with a height of 2 mm, width of 2 mm, tooth spacing of 5 mm, and a two-space pattern arrangement. Based on studies by Riyadi & Mahmudi (2021) and Ramadhan & Fauzi (2022), reducing the height and spacing of the teeth can produce finer shreds and increase coconut milk extraction efficiency. Considering these findings, a new design was proposed with 1.5 mm tooth height, 2.5 mm tooth width, 3.5 mm spacing, a cylindrical shape, and a full-space pattern. These changes aim to increase the number of cuts per cylinder rotation, produce smaller and denser coconut flakes, and reduce material loss or reduction loss. Additionally, the wider teeth produce shorter shreds, making the squeezing process easier and increasing the total milk yield.

The manufacturing process was carried out manually through hand-carving of each grater tooth. This process began with drawing guideline lines on the cylinder surface to ensure proper tooth alignment (Mudzakir et al., 2017). Next, the appropriate chisel tool was selected based on the desired tooth dimensions (Riyadi & Mahmudi, 2021). The carving followed the sketched pattern carefully to maintain consistent shape and spacing among teeth. After carving, the finishing process was performed to ensure that the final product met the proposed design specifications. The grater surface was cleaned and smoothed to remove any rough edges or carving imperfections.

The final redesigned product has a total weight of 2 kilograms, a cylinder length of 15.5 centimeters, tooth height of 1.5 millimeters, tooth width of 2.5 millimeters, and tooth spacing of 3.5 millimeters. With these specifications, the redesigned grater is expected to produce finer grated coconut, allow easier squeezing, and yield more coconut milk compared to the previous design. This improvement is also expected to reduce the high reduction rate observed in the existing grater machine.

This study concludes that the application of reverse engineering in redesigning the coconut grating machine can significantly enhance both efficiency and grating quality. The key performance factor lies in the characteristics of the grater teeth, where their dimensions and arrangement directly determine the texture of the grated coconut and the resulting milk volume. Through digital scanning, CAD-based redesign, and precise manual manufacturing, this new design not only addresses the limitations of the existing model but also serves as a potential reference for developing more efficient, ergonomic, and productive coconut grating machines in the future.

## 4. Conclusions

Based on the coconut grater design developed using the reverse engineering method, the results and conclusions were obtained in accordance with the research objectives. The redesigned coconut grater from the existing grating machine produced the following data:

the grater teeth specifications were determined to be 1.5 mm in height, 2.5 mm in width, and 3.5 mm in spacing between teeth. After testing with 10 coconuts—5 with shells and 5 without shells—the results showed a reduction difference of 27.92% between the existing grater and the proposed design, with the proposed grater exhibiting 27.92% less reduction than the existing one. Therefore, it can be concluded that this reduction difference demonstrates that the proposed grater design successfully optimized the grated coconut output and coconut milk yield.

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The author was involved in every aspect of the research.

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The author declare no conflict of interest.

## Open Access


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