Development of Production Machines to Improve the Efficiency of Snack Food Manufacturing Compared to Manual Methods

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Abstract

The snack food industry has experienced rapid growth over the past two decades, driven by lifestyle changes, urbanization, and increased demand for convenient, ready-to-eat products. Advances in food processing technology have enabled manufacturers to create tools that improve production efficiency and food safety. Increasing competition has also pushed industry players to focus on digital marketing innovation and adapt to local preferences. Overall, the snack food industry continues to grow dynamically and plays a vital role in the modern food economy. The method used in this test involves placing cooked food ingredients on a baking sheet and placing it under a press, then pressing it until it conforms to the mold. The food production test using a single press demonstrated that 49 molds could be produced within 8.53 minutes. This indicates a notable improvement in production efficiency compared to the conventional manual manufacturing method.

Keywords: *Pneumatic hydraulic, Food mold, Time.*

1. Introduction

Rengginang is one of Indonesia's well-known traditional snacks, especially on the island of Java [1]. Made from glutinous rice that is seasoned, dried, and then fried, Rengginang has a savory taste and crispy texture that is loved by many people [2]. As a traditional food product, Rengginang not only serves as a snack, but also has cultural value because it is often served at various family events and traditional ceremonies [3]. The development of the snack food industry in Indonesia has shown significant growth in line with the increasing demand for practical and long-lasting snack products [4,5]. This opens up great opportunities for traditional food products to be developed into commodities with high economic value [6]. Rengginang is one of the products with great potential for development because its manufacturing process is relatively simple, the raw materials are easily available, and it can be modified into various flavors such as original, spicy, shrimp, shrimp paste, and other modern variants [7].

Figure 1 below shows several types of Rengginang in various flavors, packaged in an attractive and modern style. Rengginang is a traditional Indonesian snack made from selected glutinous rice, processed to achieve a crispy and savory texture. The image displays a variety of flavors suitable for everyone, ranging from onion, shrimp paste, original, balado, spicy, sweet, to other unique spice blends that offer distinctive and delicious flavors.

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Figure 1. Rengginang in a variety of flavors

Figure 1 above shows several flavor variants of Rengginang, each with its own distinct advantages in terms of aroma, taste, and crispiness. This product is perfect as a daily snack, a treat to enjoy while relaxing with family, or as a regional souvenir. In addition to its delicious taste, Rengginang is made from high-quality ingredients, ensuring that its traditional flavor is preserved.

Faced with steadily rising market demand and increasingly fierce competition in the food sector, consistent quality has become a crucial factor for Rengginang business owners [8]. Hand-making Rengginang is no longer considered effective due to limited production capacity and worker fatigue, which can reduce productivity [9,10]. Furthermore, the speed and accuracy of the forming process significantly impact the final quality of Rengginang, particularly the size and density of the dough [11]. As a solution, innovations are being implemented in the form of Rengginang molding machines. This machine is designed to accelerate the molding process, improve size accuracy, and minimize damage to Rengginang caused by human fatigue [12,13]. The use of a pressing machine allows for more hygienic, efficient, and consistent processing of Rengginang, significantly increasing production capacity [14,15]. This shift from manual to mechanical methods is expected to help small and medium-sized businesses increase competitiveness, meet greater market demand, and improve overall product quality [16,17].



Figure 2. Manual manufacturing process

Figure 2 above shows the steps involved in making Rengginang by hand using simple tools. As consumer demand increases and small and medium-sized enterprises (SMEs) in the snack food sector grow, innovative equipment is needed to improve consistency of the production process [18,19]. The use of computer-aided design (CAD) technology is a crucial solution for developing ergonomic, precise, and easy-to-operate tools [20]. One widely used CAD software is SolidWorks, due to its comprehensive 3D modeling capabilities, realistic visualizations, and analysis features to check the strength, durability, and feasibility of the design [21,22]. By using SolidWorks to design the Rengginang-making machine, the design can be made more detailed and accurate, from the frame structure and the lever or hydraulic mechanisms to the molds [23]. The resulting 3D model allows the process of simulating the press machine operation before it is physically manufactured, thereby reducing the risk of design errors and reducing prototype production costs. In addition, the use of SolidWorks also facilitates the design modification process to achieve an optimal press machine design according to the manufacturer's needs [24, 25].

In the manual production of Rengginang, various challenges and product defects that affect the quality of the final product are still frequently encountered [26,27]. The manual shaping process results in inconsistent sizes and thicknesses of the Rengginang, leading to uneven cooking during drying and frying [28]. Additionally, the pressure applied manually is often inconsistent, causing the Rengginang to crack, break, or crumble before the drying process is complete. Other issues include the irregular shape of the Rengginang and the imperfect adhesion between the glutinous rice grains [29]. This can cause the Rengginang to break easily when being moved or packaged. Manual processes also require more labor and take longer to produce, resulting in low productivity and making it difficult to consistently control product quality [30]. Therefore, the use of a Rengginang press machine is necessary to make the molding process more effective and efficient. Press machines can generate more stable pressure, resulting in more uniform Rengginang shapes, sizes, and thicknesses [31]. By using press machines, the risk of damage - such as cracks, breaks, and uneven shapes - can be minimized, thereby improving product quality and optimizing production capacity.

Despite the increasing demand for traditional snack products such as Rengginang, most small and medium enterprises still rely on manual molding methods that require significant labor and production time [32]. Manual molding also tends to produce inconsistent product dimensions and uneven density, which affect the final product quality and production efficiency. Several previous studies have discussed the development of food press machines and pneumatic-based production systems for improving manufacturing performance [33]. However, most existing studies focus on general food processing equipment and conventional single-mold pressing systems, while studies specifically addressing pneumatic-hydraulic multi-mold systems for Rengginang production are still limited. In particular, limited research has evaluated the effect of cylinder variations on molding uniformity, production capacity, and operational efficiency in Rengginang manufacturing. Therefore, this study aims to design, manufacture, and evaluate a pneumatic-hydraulic Rengginang molding machine equipped with 49 molds in a single pressing cycle. The study also investigates the influence of different numbers of pneumatic-hydraulic cylinders on molding quality, thickness uniformity, density, and production efficiency. The main components made include the machine frame, press system, Rengginang mold, lever or drive system, and mold holder. The performance of the developed machine is further compared with conventional manual molding methods to determine its effectiveness in improving productivity and product consistency for small and medium-scale food industries.

2. Materials and methods

The development of a Rengginang press machine requires several materials and supporting components to ensure optimal machine performance and durability. The method used in the manufacture of the Rengginang press machine consists of several stages, including design, manufacturing, assembly, and testing. The results of this method are expected to demonstrate that using the press machine can

increase production capacity, reduce product defects, and improve the overall quality of Rengginang production.

2.1. Materials

The manufacturing process for a Rengginang press machine requires several materials and supporting components to ensure the machine's performance, strength, and durability. The primary material used for the machine frame is lightweight steel or hollow steel, as it offers good mechanical strength, is easy to fabricate, and can support the entire machine structure during operation. Stainless steel is used for the molds and components that come into direct contact with food products because it is corrosion-resistant, hygienic, and safe for use in food processing. The pneumatic-hydraulic system uses pneumatic cylinders or hydraulic cylinders as the main components to generate compressive force. These cylinders are supported by other components such as pistons, high-pressure hoses, control valves, pressure regulators, and pressure gauges to regulate and control air or fluid pressure during the pressing process. In addition, an air compressor is used as a power source in the pneumatic system to generate stable air pressure. In the hydraulic system, hydraulic oil is used as the pressure-transmitting medium so that the pressing process can proceed more optimally and evenly. Other supporting components include bolts, nuts, and an electrical panel consisting of cables, switches, and control buttons. The fabrication process also utilizes welding electrodes, grinding wheels, lubricants, and finishing paint to support the assembly process, provide corrosion protection, and enhance the quality and durability of the pneumatic-hydraulic-based Rengginang press machine.

2.2. Methods

Before conducting the research, a research flowchart was developed to provide a systematic and well-structured guideline for the entire study. The flowchart serves as a reference for each stage of the research process, ensuring that the activities are carried out in accordance with the planned methodology and objectives. In this study entitled "Development of Production Machines to Improve the Efficiency of Snack Food Manufacturing Compared to Manual Methods," the flowchart illustrates the sequence of activities starting from problem identification, literature review, machine design, manufacturing process, machine testing, data collection, performance evaluation, and comparison with conventional manual production methods. By establishing a clear research workflow, the study can be conducted more effectively, systematically, and in a directed manner to achieve accurate and reliable results.

The flowchart in Figure 3 represents the research methodology for the development of a pneumatic-hydraulic Rengginang molding machine, presented in Figure 3. This research began by identifying machine requirements and production specifications based on production capacity, mold dimensions, and the operational needs of Rengginang MSMEs. After determining these specifications, machine components were designed using SolidWorks software to produce detailed three-dimensional models of the frame, mold system, and pneumatic-hydraulic mechanism. The next stage included the selection of materials and components based on strength, durability, and safety requirements for food use. After the design stage was completed, the machine components were manufactured and assembled into a complete molding system. Mechanical tests without dough were then conducted to evaluate the performance of the pneumatic and hydraulic systems, including pressure stability, actuator movement, and frame stability. Following the mechanical tests, experimental trials were conducted with Rengginang dough using various pneumatic-hydraulic cylinder variants. Mold quality, thickness uniformity, density, and production time were evaluated. Finally, the production performance of the developed machine was compared with conventional manual molding methods to determine improvements in efficiency and production capacity.

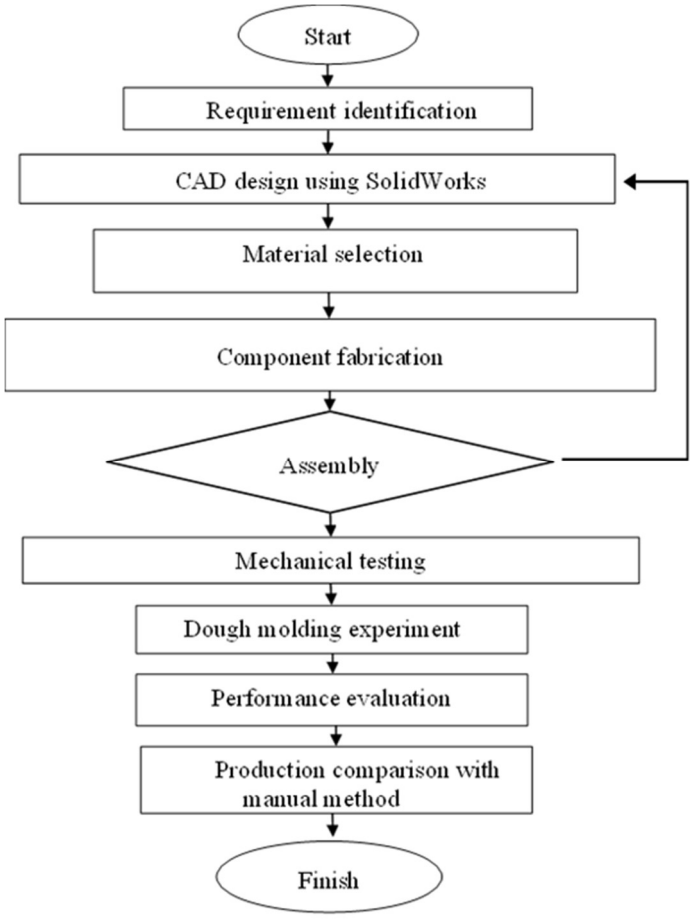


Figure 3. Experimental Procedure Flowchart

2.2.1. Identify machine requirements and specifications

Material identification was conducted to design a Rengginang-making machine capable of increasing production capacity, ensuring uniformity in shape and size, and improving time and labor efficiency. The Rengginang forming machine is equipped with a pressing system designed to support the production of Rengginang from steamed glutinous rice, producing products with uniform and consistent shapes and sizes. This machine is capable of producing 49 (forty-nine) pieces of Rengginang in a single batch. The printing machine is designed to produce Rengginang with diameter 50 mm, with outer thickness 10 mm as well as inner thickness 5 mm, thus producing precise Rengginang shapes that meet product standards. The machine's working system uses semi-automatic system, where the material filling process is carried out manually, while the pressing process is carried out automatically with working pressure: ±50–150 kg/cm², to increase work efficiency and reduce dependence on human power. The main power source of the machine uses pneumatic system supported by air compressor, so that the pressing pressure can be regulated stably, safely, and consistently. The use of a pneumatic system also aims to increase production speed and extend the life of machine components. All machine parts that come into direct contact with food must be made of food-grade stainless steel (SS 304), , easy to clean, and resistant to corrosion, so that food hygiene and safety standards can be maintained properly in accordance with food industry regulations. The machine weighs approximately 70 kg with a one-way (top-down) press mold. For this, an actuator drive unit is needed to produce motion or force, which is

the end result or output of the conversion of energy from pneumatic forging to mechanical. To determine the diameter of the pneumatic cylinder that corresponds to the required force, it can be calculated using the following equations. The equations can be written and defined as follows:

$$d = \sqrt{\frac{4F}{\sigma_y \pi}} \quad (1)$$

Where:

- d = diameter of the component or shaft (mm)
- F = applied force or pressing force (N)
- σ_y= yield strength of the material (MPa or N/mm²)
- π = mathematical constant pi (3.14)
- P = working pressure (Pa or N/m²)
- A = cross-sectional area of the pressing surface (mm² or m²)

Definition of the Second Equation

$$P = \sqrt{\frac{F}{A}} \quad (2)$$

Where:

- P= pressure or calculated parameter
- F= applied force/load (N)
- A= cross-sectional area (mm² or m²)

This equation describes the relationship between force and cross-sectional area.

Explanation:
The first equation is used to determine the minimum diameter of a component based on the applied load and the material yield strength to prevent permanent deformation. The second equation is used to calculate the working pressure generated by the applied force over a specific cross-sectional area in the pressing system.

Calculating the force of a pneumatic cylinder when pressing, effective piston force for forward stroke;

$$F = A \; x \; P \quad (3)$$

Effective piston force during retraction

$$F = A \; x \; P \quad (4)$$

The equation shown in the image can be written as:

$$A = \frac{\pi}{4}(D^2 - d^2) \quad (5)$$

This equation is used to calculate the cross-sectional area of a hollow circular object, such as a pipe, tube, or hollow shaft.
Where:

- A= cross-sectional area (mm^2 or m^2)
- π= mathematical constant pi (3.14)
- D= outer diameter of the hollow object
- d= inner diameter of the hollow object

Compressor discharge

The equation shown in the image can be written as:

$$Q = \frac{\pi}{4} D^2 \times v \quad (6)$$

This equation is used to calculate the flow rate of a fluid flowing through a circular pipe or tube.
Where:

- Q= volumetric flow rate (m^3/s)
- π= mathematical constant pi (3.14)
- D= diameter of the pipe or tube (m)
- v= fluid velocity (m/s)

Pneumatic cylinder stroke time, piston forward step time

The equations shown in the image can be written as:

$$t_1 = \frac{A \times h}{Q \times 1000} \quad (7)$$

Where:

- t_1= time required for the process (s or min)
- A= cross-sectional area (mm^2 or m^2)
- h= height or stroke length (mm)
- Q= flow rate $(L/min$ or $m^3/s)$
- 1000= conversion factor used to adjust the unit system

$$A = \frac{\pi}{4} D^2 \quad (8)$$

Where:

- A= circular cross-sectional area
- π= mathematical constant pi (≈ 3.14)
- D= diameter of the cylinder or pipe

Piston stroke time

The equations shown in the formula can be written as:

$$t_2 = \frac{(A_1 \times A_2) \times h}{Q \times 1000} \quad (9)$$

Where:

- t_2= time required for the return or working stroke (s or min)
- A_1= first effective area (mm^2 or m^2)
- A_2= second effective area (mm^2 or m^2)
- h= stroke length or movement distance (mm)
- Q= fluid flow rate $(L/min$ or $m^3/s)$
- 1000= unit conversion factor

Description
This equation is commonly used in hydraulic and pneumatic systems to determine the operating time of a cylinder or actuator during a specific motion process. The required time depends on the effective working area, stroke length, and flow rate of the fluid.

$$A = \frac{\pi}{4} d^2 \quad (10)$$

Where:

- A= circular cross-sectional area
- π= mathematical constant pi (3.14)
- d= diameter of the piston rod or circular component

Description
This equation calculates the area of a circular section based on its diameter. In hydraulic and pneumatic calculations, this area is often used to determine pressure, force, and fluid flow characteristics.

Piston speed

The equation shown in the formula can be written as:

$$\boldsymbol{V = \frac{s}{t}} \quad (11)$$

Where:

- V= velocity or speed (m/s)
- s= distance or displacement traveled (m)
- t= time required for the movement (s)

Description
This equation is used to calculate the velocity of an object by dividing the traveled distance by the required time.

Air consumption in pneumatic cylinders, air consumption while advancing

The equation shown in the formula can be written as:

$$V = \frac{\pi}{4} D^2 \times h \quad (12)$$

Where:

- V= volume (mm^3, cm^3, or m^3)
- π= mathematical constant pi (3.14)
- D= diameter of the cylinder or circular object
- h= height, length, or stroke of the cylinder

Description
This equation is used to calculate the volume of a cylindrical object or space.
The formula is derived from:

$$\text{Volume} = \text{Area of base} \times \text{Height}$$

For a circular base:

$$A = \frac{\pi}{4} D^2$$

Substituting the circular area equation into the volume equation gives:

$$V = \frac{\pi}{4} D^2 \times h$$

This equation is commonly used in mechanical engineering, hydraulic systems, pneumatic cylinders, and fluid mechanics to determine the volume capacity of cylindrical components.

Air consumption when reversing

The equation shown in the formula can be written as:

$$V = \frac{\pi}{4}(D^2 - d^2) \times h \quad (13)$$

Where:

- V= air consumption volume
- D= cylinder bore diameter
- d= piston rod diameter
- h= stroke length
- π= mathematical constant pi (3.14)

Description

- During the forward stroke, air fills the full piston area.
- During the reverse stroke, air fills the annular area because part of the area is occupied by the piston rod.
- Therefore, the reverse air consumption is usually smaller than the forward air consumption.

2.2.2. Component manufacturing

The manufacturing of Rengginang printing press machine components aims to produce a tool capable of printing Rengginang dough uniformly, quickly, and efficiently. The manufacturing process begins with designing components according to production capacity requirements and food safety standards. The main components include the machine frame, press system, Rengginang mold, lever or drive system, and mold holder. The press system is designed to be able to provide even pressure so that the print results have a uniform thickness and shape. The Rengginang mold is made of food-grade materials such as stainless steel or aluminum to maintain product cleanliness and safety. All components are assembled with attention to accuracy, connection strength, and ease of operation. After the assembly process is complete, the machine is tested to ensure all components function properly and produce Rengginang according to standards, namely all machine components are completed.

2.2.3. Machine assembly

The machine assembly process begins with assembling the main frame as the basic structure that supports all components. The frame is welded precisely to ensure the strength and stability of the machine during operation. Next, the mold is installed on its stand, paying attention to the position and alignment to match the machine's working design. After the mold is installed, the pressing system is installed and adjusted to be able to work optimally in providing even pressure. The next step is to connect the compressor hose to the pneumatic system, ensuring that each connection is tightly connected and there are no air leaks. The final stage of assembly is the precise adjustment of the mold position. This adjustment is carried out to ensure alignment between the mold and the pressing system, so that the machine's work results are optimal, accurate, and consistent according to the established standards, namely the Rengginang printing machine has been assembled.

2.2.4. Mechanical testing with dough

Mechanical testing of the machine was conducted after the entire assembly process was completed, without using the Rengginang dough. This test aimed to ensure all mechanical components and pneumatic systems were functioning properly before the machine was used in the production process. The test began by running the machine empty to check the stability of the frame, the smooth

movement of the pressing system, and ensure there were no vibrations or abnormal sounds. Next, the pneumatic system was checked by flowing air from the compressor, to ensure the air pressure was working as needed and there were no leaks in the hoses or connections. In addition, observations were made to the alignment and precision of the mold movement when the pressing system was operated. Readjustments were made if any misalignments were found. The test results showed that the machine could operate well mechanically and was ready for the next testing stage using work materials, with the final result being the machine ready for testing with materials.

Table 1. Performance evaluation of the developed press machine

Parameter	yield	Performance force
Air pressure	0.752	0.759
Ambient Temperature	0.853	0.854
Room Humidity	0.892	0.892
Weight of Hole Dough	0.927	0.928

2.2.5. Dough molding experiment

During the refinement and finishing stage of the Rengginang press machine development, several optimization processes were carried out to improve printing accuracy, structural strength, operational safety, and overall machine performance. The mold components were recalibrated and readjusted to achieve a more precise pressing process and to ensure uniform Rengginang shapes in accordance with the predetermined design specifications. Subsequently, structural reinforcement was applied to several machine components identified as having lower rigidity or excessive vibration during preliminary testing. This reinforcement process aimed to improve the machine's stability, durability, and operational reliability during continuous production activities. In addition, all sharp edges and rough surfaces were carefully smoothed and refined to minimize the risk of damage to the Rengginang dough while simultaneously enhancing operator safety and ease of handling. The finishing stage also included a comprehensive cleaning process to remove residual materials, metal particles, dust, and other contaminants generated during fabrication and assembly. This procedure was essential to maintain machine cleanliness, support food-grade production standards, and ensure the quality and hygiene of the final product.

2.2.6. Experimental machine design trial

Production and operational testing of the Rengginang press machine is conducted through a continuous production test process to ensure the machine's stable operation over a specified period. At this stage, hourly production capacity is measured to determine the machine's efficiency and productivity. Furthermore, machine durability is checked by monitoring component performance during the test run. Operators are also directly trained in the machine's use, so that at the end of the test, it can be concluded that the machine is suitable for routine production at both the MSME and industrial scale.

2.2.7. Product comparison with manual method

Based on the results of trials, refinements, and production and operational tests, the Rengginang press machine has met the established criteria. The machine was declared ready for use because it operated safely and efficiently and produced consistent products in terms of shape, density, and

thickness. Therefore, the machine is ready for implementation in the routine Rengginang production process.

3. Results and discussion

3.1. Design and manufacture of tools

The image below shows the design stages in the development of a Rengginang pressing machine, from the conceptual design phase to the final product. The process begins with the design of the machine frame, which serves as the main support structure to ensure stability and strength during operation. Next, a basic mold design is developed as the foundation for the molding system, followed by a mold design process that determines the shape and dimensions of the Rengginang product. After that, a tray design is created to support the placement and handling of the molded product during the production process. All designed components are then integrated during the assembly phase to ensure proper mechanical and functional operation of the machine. The final stage produces a complete Rengginang pressing machine prototype that is ready for testing and implementation in snack production.

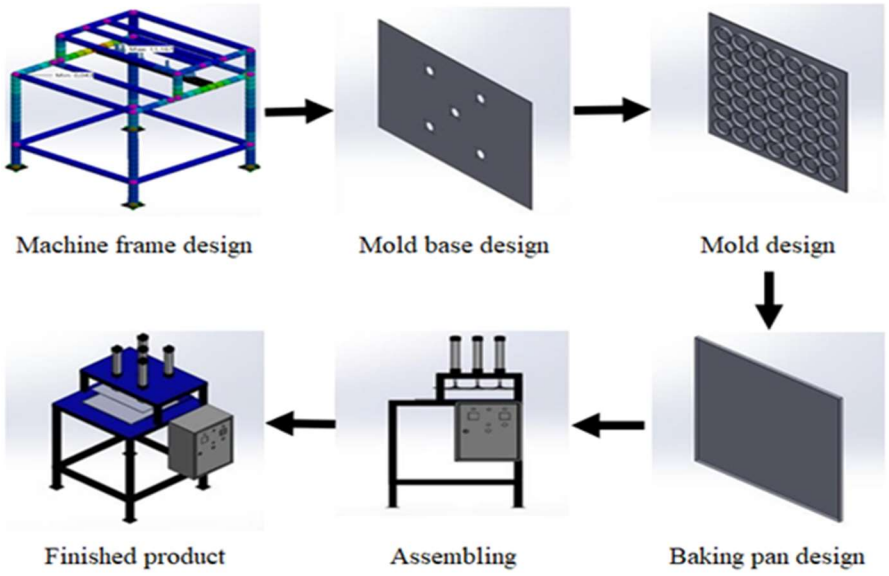


Figure 4. Design of the press machine and its accessories

Figure 4 is the manufacturing process to the completion of machine assembly. The Rengginang pressing machine will be implemented as an alternative production system to replace conventional manual labor in snack making. The developed machine is capable of carrying out the pressing and molding process more efficiently, consistently, and hygienically compared to traditional manual methods. By utilizing a mechanical pressing system, this machine reduces dependence on human labor and increases production capacity in shorter processing times. In addition, the application of this machine increases the uniformity of product shape and size, thereby improving product quality and production standardization. The implementation of this machine is expected to support small- and medium-scale snack industries in increasing productivity, reducing operational costs, and optimizing the overall manufacturing process. Furthermore, the adoption of mechanical production technology contributes to the modernization of traditional food processing systems while maintaining the quality and characteristics of Rengginang products.

3.2. Pneumatic hydraulic pressure test

Tests were conducted with varying pressures to determine the optimal pressure capable of producing Rengginang with uniform shape and thickness. The test results showed that at a certain working pressure, the pneumatic-hydraulic system was able to provide sufficient pressure to compact the dough without damaging the Rengginang structure. Pressure that was too low resulted in less dense molds and uneven thickness, while pressure that was too high could potentially damage the Rengginang shape. The optimal pressure produced Rengginang with a good level of density and a uniform shape across all 49 molds.

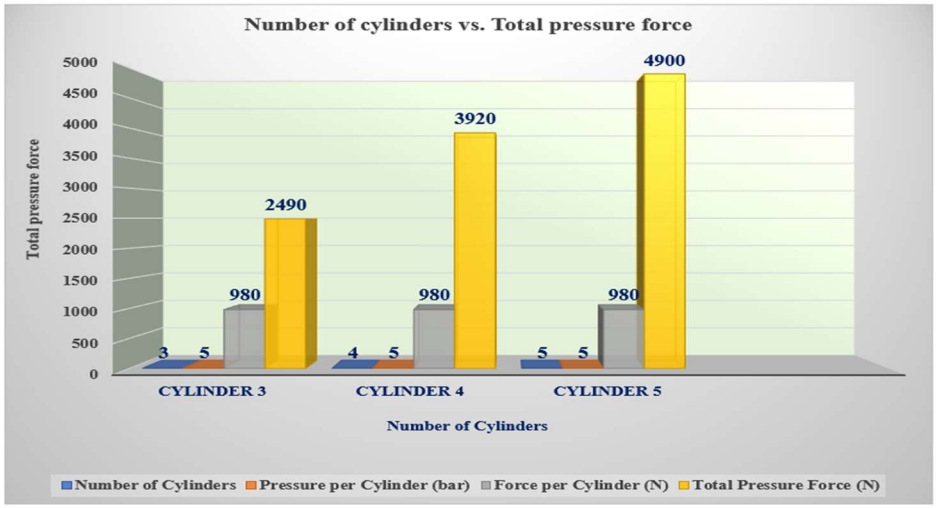


Figure 5. Increased hydraulic-pneumatic cylinder pressure on the dough in the mold

In Figure 5, the Rengginang pressing system uses a pneumatic-hydraulic cylinder-based pressing mechanism. One pneumatic cylinder with a working pressure of 5 bar produces a relatively small pressing force, so it is not yet able to form the mold optimally. To increase the pressing force, the number of cylinders used was varied. In initial testing using 3 pneumatic–hydraulic cylinders, the resulting compressive force was 2490 N. However, in this condition, the Rengginang molding results still did not show good quality because the pressure applied was not sufficient to form the desired structure. Furthermore, the use of 4 pneumatic–hydraulic cylinders increased the compressive force to 3920 N. Despite the increase in pressure, the pressing results obtained were still imperfect, characterized by uneven mold shapes and suboptimal density. The best results were obtained using 5 pneumatic–hydraulic cylinders, where the maximum compressive force generated reached 4900 N. Under these conditions, the Rengginang pressing process showed perfect results, with a neat, solid mold shape that met the expected specifications. Thus, it can be concluded that the optimal pressing force requirement for the Rengginang pressing process is in the range 4900 N.

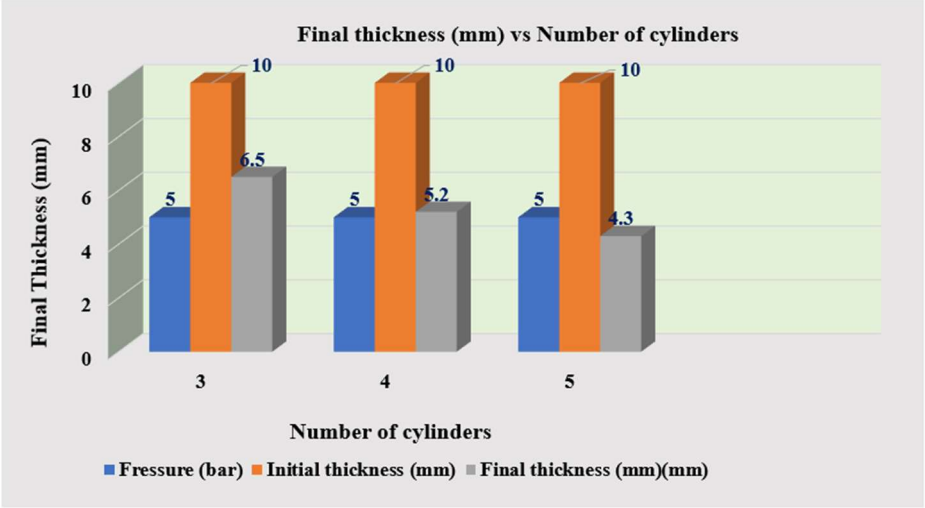


Figure 6. Final compression thickness from pressure variations

In Figure 6, the Rengginang pressing process is carried out using a pneumatic-hydraulic system with a variation in the number of cylinders as follows: 3, 4, and 5 cylinders. Each pneumatic-hydraulic cylinder operates at the same pressure, namely 5 bar, so the difference in pressing results is influenced by the number of cylinders used. Before pressing, the Rengginang dough had an initial thickness of 10 mm. After the pressing process using 3 pneumatic–hydraulic cylinders, the final thickness of the dough was reduced to 6.5 mm. These results indicate that the resulting compressive force is still not optimal for producing Rengginang with the desired thickness. In the use of 4 pneumatic–hydraulic cylinders, the final thickness of the dough was reduced to 5.2 mm. This indicates an increase in pressing force, which causes the dough to become denser and more even compared to using 3 cylinders. Furthermore, pressing using 5 pneumatic–hydraulic cylinders produced the smallest final thickness, namely 4.3 mm. This condition indicates that the more cylinders used, the greater the resulting pressing force, resulting in a thinner, denser, and more uniform Rengginang dough. Therefore, the use of 5 pneumatic-hydraulic cylinders provides the most optimal pressing results compared to other variations in the number of cylinders.

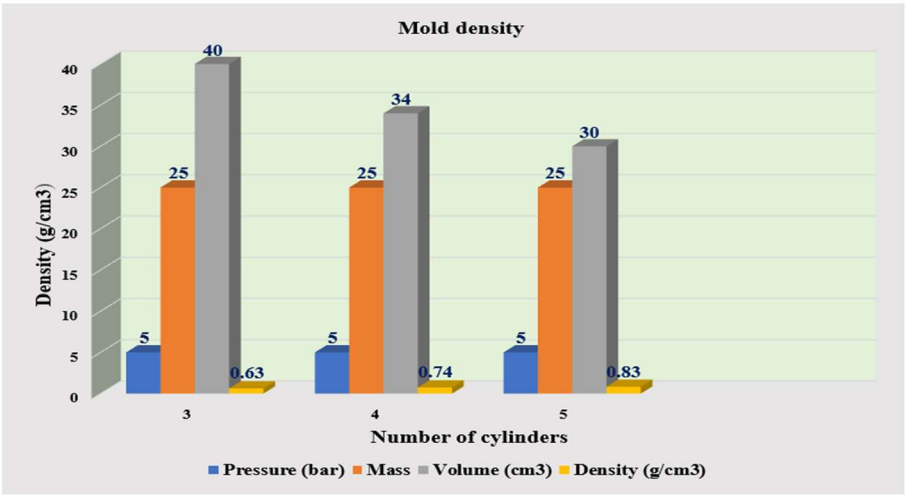


Figure 7. Density of mold

Figure 7 shows that the density of the Rengginang pressing results is influenced by the magnitude of the pressing force generated by the pneumatic-hydraulic system. In this study, variations in the number of pneumatic-hydraulic cylinders were used, namely 3, 4, and 5 cylinders, with the same working pressure on each cylinder, namely 5 bar. The test results show that the use of 3 pneumatic–hydraulic cylinders produced a density value of 0.63 g/cm³. This value indicates that the level of compaction of the dough is still relatively low, so the Rengginang structure has not been formed optimally. In the variation of use 4 pneumatic–hydraulic cylinders, the density value increased to 0.74 g/cm³. This increase indicates that greater pressure is able to compact the dough better, so that the air cavities in the dough are reduced. Meanwhile, the use of 5 pneumatic–hydraulic cylinders produced the highest density value, specifically 0.83 g/cm³. These results indicate that increasing the number of cylinders produces a greater and more even pressing force, thus optimizing the density of the Rengginang. Therefore, it can be concluded that the greater the number of pneumatic-hydraulic cylinders used at a pressure of 5 bar, the higher the density of the Rengginang pressing results.

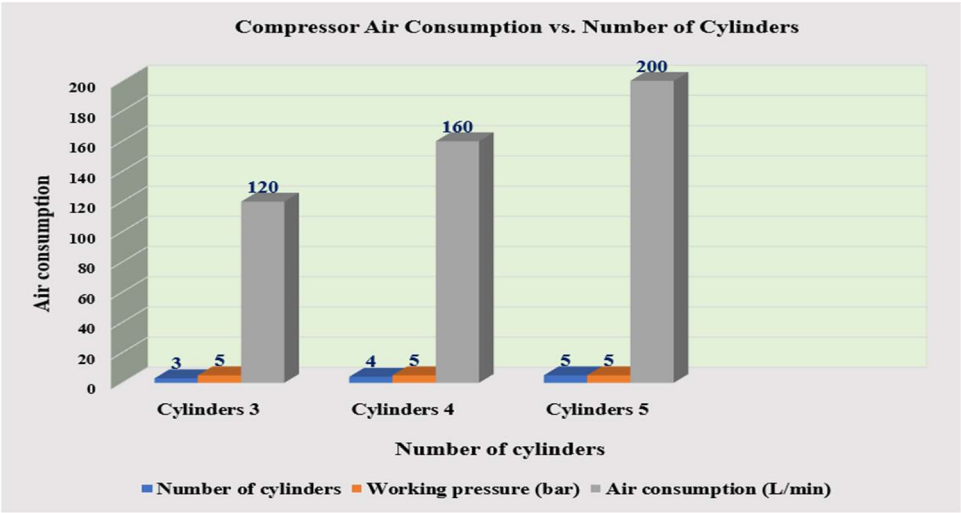


Figure 8. Compressor air consumption to drive pneumatic hydraulic

Figure 8 shows that the air requirement from the compressor is an important factor in the pressing and molding process of Rengginang using a hydraulic-pneumatic system. In this study, variations in the number of pneumatic-hydraulic cylinders were used: 3, 4, and 5 cylinders, with the air supply coming from a single compressor. Pressurized air was supplied to each cylinder through a hose with diameter 10 mm. On the use 3 pneumatic–hydraulic cylinders, the air requirement from the compressor was still relatively low. Air flow through a 10 mm diameter hose was sufficient to meet the cylinder's working needs, allowing the pressing and molding process to proceed stably without significant pressure drop. When the number of cylinders was increased to 4 pneumatic–hydraulic cylinders, the compressor's air requirements increased. This was due to the increased air volume required to operate all cylinders simultaneously. However, with a 10 mm hose diameter, the air supply could still be distributed well, ensuring the pressing process continues normally. Depending on the usage variations 5 pneumatic–hydraulic cylinders, the air requirement from the compressor was the greatest. The compressor must be able to supply a larger and continuous amount of air to maintain the working pressure in each cylinder. A hose with a diameter of 10 mm played a crucial role in maintaining smooth air flow, thus minimizing cylinder response delays and decreasing pressing performance. Thus, it can be concluded that the more pneumatic-hydraulic cylinders used in the Rengginang pressing and molding process, the greater the air requirement from the compressor. Selecting the appropriate compressor capacity and hose diameter is an important factor in ensuring the pressing process is effective and optimal.

3.3. Quality of rengginang printing

Based on the test results, the resulting Rengginang exhibited a fairly good level of uniformity in terms of diameter, thickness, and weight. Most of the molds showed a neat shape and no cracks or deformation. The pressure distribution between the center and edge of the mold shows relatively little difference, thus concluding that the pneumatic-hydraulic system is capable of distributing pressure evenly. This is a major advantage over manual pressing methods, which tend to produce uneven thickness.

Table 2. Production Results per cycle (49 pieces)

Parameter	yield	Performance notes
Number of prints filled	49	According to capacity
The number of rengginang successfully printed	49	Nothing fails
Defective print	0	--
Average weight of the print	11.8 g	Slight shrinkage after pressing
Surface Flatness	95% average	2-3 surfaces are slightly uneven but still within limits

Table 2 summarizes the production performance per cycle. A total of 49 products were successfully manufactured without defects, demonstrating consistent operational capability. The produced parts exhibited an average weight of 11.8 g with minor post-press shrinkage. Furthermore, the average surface flatness reached 95%, with slight irregularities observed on several surfaces but still within the allowable tolerance range.

3.4. Comparison of the quality of Rengginang printing results with conventional ones

Figure 9 shows that using a Rengginang printing machine with a single printing capacity of 49 pieces yields far superior results compared to manual methods. This press machine results in more uniform size and shape, even thickness, and a neater appearance, thus increasing the product's selling value. The printing process also takes place more quickly and efficiently, saving significant time and labor. In contrast, manual printing methods still rely heavily on labor skills. Print results tend to be not uniform, both in terms of size and thickness, resulting in less consistent product quality. Furthermore, manual processes require more time and effort to produce the same quantity. Therefore, using a 49-piece printer per print run not only increases productivity, but also guarantees quality and consistency of print results, so it is more effective to meet production needs on a larger scale.

In Figure 9, in the manual Rengginang printing process, the dough needs to be hot and cooked and the hand speed in printing must be fast, because if the material to be printed is cold, it will harden. Hot dough has a better texture - soft and flexible - so it is easy to shape using your hands. When the dough is cold, the texture will harden and become stiff, making it difficult, if not impossible, to shape manually. Therefore, manual Rengginang molding must be done quickly to ensure the dough remains warm and the shaping process can proceed smoothly.

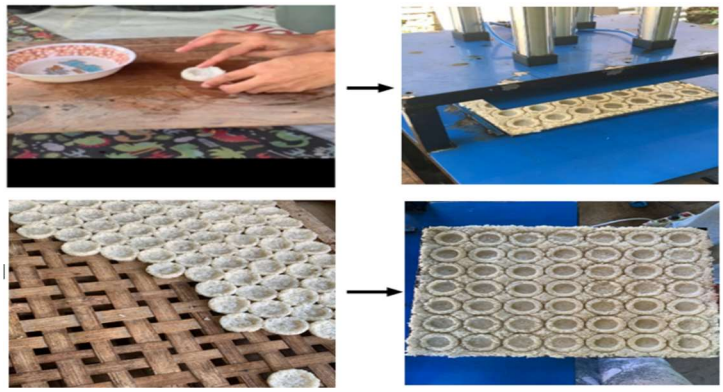


Figure 9. Manual molding vs. press machine

3.5. Production capacity and time efficiency

By using 5 hydraulic pneumatic units in the Rengginang printing process, it provides a significant increase in production capacity and time efficiency. With the ability of one print producing 49 pieces, this system is capable of producing Rengginang in large quantities in a fast and consistent manner. The printing process can be repeated in a short time, increasing production output without requiring a large additional workforce. In contrast, manual printing methods have a relatively low production capacity, and it relies heavily on the worker's speed and skill. Printing also takes longer, especially as the mixture begins to cool and harden, requiring a fast and often inefficient process. Therefore, the use of five pneumatic hydraulic machines with a capacity of 49 pieces per print proved to be effective. It increases productivity, saves production time, and reduces workload, so it is more effective than manual printing methods, especially for medium- to large-scale Rengginang production.

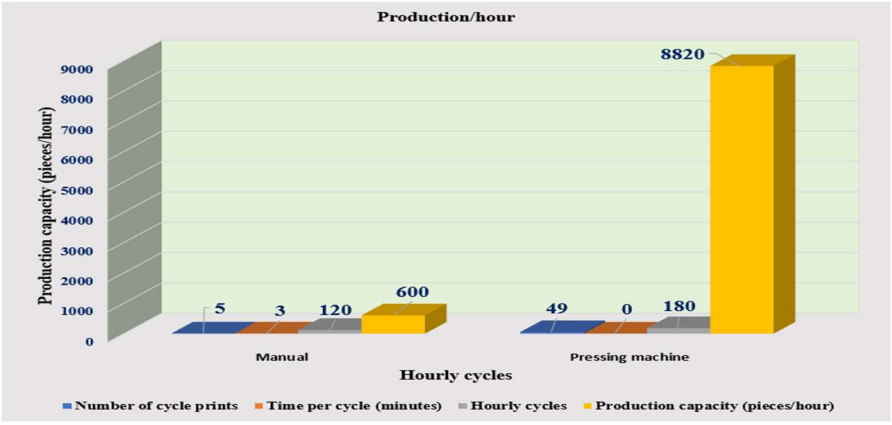


Figure 10. Production capacity and time efficiency

Figure 10 shows the results of Rengginang pressing process being carried out one by one with an average time of 3 minutes for each piece, so that in one hour only around 600 rengginang pieces can be produced. Meanwhile, the use of a hydraulic-pneumatic press machine equipped with 49 molds in one pressing process and using 5 pneumatic-hydraulic cylinders can drastically increase production capacity. With a working cycle time of around 8.53 minutes, the press machine can perform approximately 180

cycles in one hour. Thus, the resulting production capacity reaches around 8.820 Rengginang pieces per hour. This comparison shows that the use of a hydraulic-pneumatic press machine can increase production capacity up to tens of times compared to the manual method, making it very effective for increasing productivity and meeting large-scale production needs. Thus, the machine capacity is 14.7 times greater than the manual method.

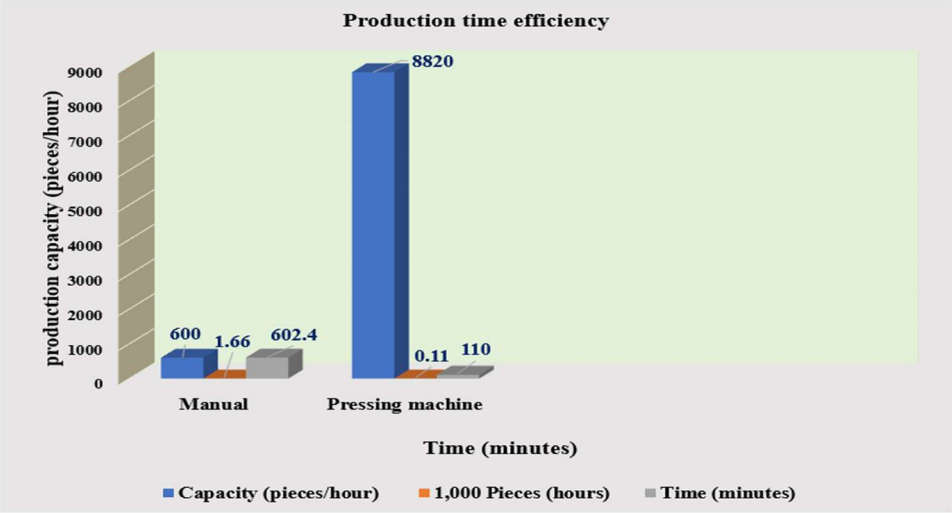


Figure 12. Production time efficiency

Figure 12 shows that production time efficiency is an important indicator of the production process. Calculations show that the manual method takes a relatively long time because the pressing process is carried out one by one and is highly dependent on hand speed and endurance. To produce 1,000 pieces of Rengginang, the manual method requires approximately 1.66 hours or the equivalent of 2 hours and 6 minutes. In contrast to the manual method, the use of a hydraulic-pneumatic press machine equipped with 49 molds in one pressing process and supported by 5 pneumatic-hydraulic cylinders can significantly speed up the production process. With a production capacity of 8.820 pieces per hour, the time required to produce 1.000 pieces of Rengginang is only approximately 0.11 hours or the equivalent of 6.8 minutes. These results indicate that the use of a hydraulic-pneumatic press machine can increase production time efficiency by approximately 97% compared to the manual method. This increase in efficiency not only speeds up the production process, but also reduces labor fatigue and increases the effectiveness and continuity of the Rengginang production process. Thus, time efficiency increases by ± 36.76% with the pressing machine.

4. Conclusion

The use of a pneumatic system has been proven to increase productivity and time efficiency compared to manual molding, because the pressing process can be carried out simultaneously and with more consistent pressure. Variations in the number of pneumatic cylinders have an impact on the quality and uniformity of the molding results. The more pneumatic cylinders used, the more evenly the pressure produced so the shape and thickness of the Rengginang are more uniform. The tool with 5 pneumatic cylinders shows the most optimal performance compared to variations of 3 and 4 cylinders, in terms of aspects of shape uniformity, pressure stability, and neater molding results. Compared to manual molding, the pneumatic molding and pressing tool can reduce dependence on human power, minimize operator fatigue, and improve product quality consistency. Thus, this pneumatic-based Rengginang

molding and pressing tool is worthy of being implemented as an alternative appropriate technology for small and medium businesses in increasing production capacity and quality of Rengginang. By using a hydraulic pneumatic printing machine and press, production capacity increases up to 14.7 times greater than manual and is able to reduce time efficiency by ±36.76%.

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Conflict of Interest

We declare no conflict regarding the publication of the study.

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