The design and application of cracker dough kneading machine for increasing productivity and quality of mackerel crackers in Tambakasri village Malang

Y Hendrawan¹, S Sandra¹, H N Utami² and R Damayanti¹

¹Department of Agricultural Engineering, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia
²Department of Business Administration, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia

E-mail: yusuf_h@ub.ac.id

Abstract. Mackerel cracker is a type of fish crackers with the basic ingredients of mackerel fish. The potential of mackerel fish production reaches 5000 tons/year. Moreover, it is supported by the Indonesian government’s policies which currently make the marine sector a superior program, so that business licensing of marine and fishery products can be faster. Mackerel cracker processing industry in Tambakasri village, Malang, Indonesia is still facing problems in its production process. This research was conducted in a small and medium-sized enterprise (SMEs) Yuan Mina Kartika which produces various fish crackers. The constraints in the SMEs include 1) the amount of production that has not been optimal, because of the inadequate production tools; 2) the process of refining fish that still uses traditional tools; 3) the process of kneading is done manually so that it takes a long time and produces uneven mackerel fish mixture. The purpose of this study is to develop and to test a cracker dough kneading machine to increase the productivity and quality of cracker products. Dough kneading machine uses a kneading system that is driven using an electric motor and transmission. Engine capacity is designed for 100 kg/hour using 1.5 HP with some outputs of dough tube. The test results showed a significant increase in time efficiency in the kneading process as well as the quality of the cracker dough which was better than the manual method.

1. Introduction

Indonesia's geographical location which is surrounded by the sea is an advantage for Indonesia in the fisheries and marine sector. Demand for marine products which has increased every year has a positive impact on the economy of coastal communities [1, 2]. So that led to the idea of innovation in the form of processed fish products that are diverse and will continue to grow, one of which is fish crackers as a snack and demanded by various groups. One of the small and medium-sized enterprises (SMEs) that utilize the opportunity to process fish products into processed fish cracker products is Yuan Mina Kartika SMEs, which processes Mackerel crackers. Mackerel crackers are a type of fish crackers...
based on mackerel fish meat, tapioca flour, and additives such as chicken eggs, salt, sugar, and other seasonings. The potential of mackerel fish reaches 5000 tons/year. Mackerel fish is not seasonal, which means it is available throughout the year [3]. Mackerel crackers can be one of the souvenirs and characteristics of Malang city, Indonesia so that efforts are needed in the availability of raw materials, production with good technology implementation and marketing expansion at the national level.

Yuan Mina Kartika SMEs produce 30 kg/day of crackers so that it is still classified as a small industry. The processing of mackerel cracker production at Yuan Mina Kartika SMEs still uses manual equipment so that it cannot increase its production capacity. The processing of mackerel crackers was started from removing gills, thorns, and the fish droppings, then rinsing with clean water [4]. Fish smoothing is done in the traditional way and then mixed with flour and spices. The large dough is formed and steamed for about 1 hour then sliced lengthwise with a thickness of 0.5-1 cm. The next process is dried and fried. The main problem in the production process of mackerel crackers in Yuan Mina Kartika SMEs is the dough scraping that must be done many times, the skills of the workers, and requires long production time. Therefore, it is necessary to develop a cracker dough kneading machine to increase the productivity and quality of cracker products.

2. Materials and Method
The activities were carried out from May to August 2019 by conducting surveys related to field conditions and conducting interviews and field observations. Based on surveys and interviews, it is known that SMEs have the desire to get technological improvements to facilitate the productivity of mackerel crackers and advance their business by improving product quality. The implementation of activities is focused on appropriate technological innovation that meets the requirements of low technology, low investment, and marketable, in the form of a cracker dough kneading machine. The research method used in this study is the engineering method. The engineering method is to carry out a plan activity, design, construction, applied which is not routine, so that there are modifications and new contributions, both in the form of processes and products [5]. Research using this engineering method consists of several stages [6]. These stages can be seen in Figure 1.

2.1. Design criteria
The application of appropriate design can increase productivity optimally [7]. The design criteria for the dough kneading machine are expected to meet the following criteria:
   a. Can crush flour and fish mixture so that it is non-sticky;
   b. There are some output pipes for the output of the dough to facilitate the expenditure of the dough;
   c. Machine parts that come in direct contact with food are made of stainless steel;
   d. The drive uses an electric motor with a power less than 2 HP, adjusted to the maximum power of Yuan Mina Kartika SMEs;
   e. The transmission system uses pulleys, belts, sprockets, and chains.

2.2. Functional design
The functional design is the result of the design of a component of a system that has a mutual support function to run the system. The functional design of the dough kneader machine is as follows:
   a. The engine frame serves to withstand the heavy load of the main components of the engine;
   b. Screw serves to pulverize the dough;
   c. The output pipe functions as material expenditure;
   d. The intake funnel functions as the dough feeder;
   e. Transmission system for moving screws and pulverizing dough;
   f. 1.5 HP electric motor is used as propulsion;
   g. The gearbox is used as a speed reducer.
2.3. Structural design
Structural design is carried out to determine the components and structure of the machine design that will be realized in accordance with the criteria to produce clean dough optimally.

a. Frame: material to be used in the framework of iron UNP, iron plate, and iron elbow. The frame on the dough kneader machine has dimensions of $125 \times 50 \times 70$ cm;
b. The output of the dough is made of stainless steel with a diameter of 2.54 cm;
c. A stainless-steel screw with a diameter of 12.7 cm and length of 55 cm;
d. The transmission system uses 2 pulleys, 1 v-belt. The belt connects the pulley on the motor to the pulley on the gearbox. Sprockets and chains are used as transmissions connecting from the gearbox to the screw pipe.

![Diagram](image.png)

**Figure 1.** Stages of dough kneading machine research

2.4. Technical analysis
Technical analysis is intended to determine the strength of the material from each machine component which is done by doing theoretical calculations and direct observations that occur in the field.

a. Power requirements: an analysis is carried out to determine the power needed by the engine in running the engine from the beginning to the end of both the transmission drive and cylinder rotation [8]. Calculation of engine power requirements can be calculated as follows:

$$P = \frac{2\pi \times M_t \times n}{60}$$

where: $P =$ power needed by the drive motor (W); $n =$ pulley rotation speed (rpm); $M_t =$ twisting moment (Nm).
b. Transmission unit analysis aims to determine the number of belts and pulleys needed in engine transmission. In determining the length of the belt used it can be calculated using the following equation:

\[ L = 2C + \frac{\pi}{2} (D_p + d_p) + \frac{1}{4C} (D_p - d_p)^2 \]

where:  
- \( L \) = belt length (m); 
- \( C \) = distance between two axes (m); 
- \( D_p \) = large diameter pulleys (m); 
- \( d_p \) = small diameter pulleys (m).

Belt contact angles can be calculated using the following equation:

\[ \alpha_1 = 180 \pm 2 \cdot \arcsin \left( \frac{R - r}{C} \right) \]

where:  
- \( \alpha_1 \) = belt contact angle; 
- \( R \) = large pulley radius (m); 
- \( r \) = small pulley fingers (m).

If the \( v \)-belt works to continue the moment, the stress will increase on the tensile side \( T_1 \) (the long part of the tensiled belt) and decrease on the loose side \( T_2 \) (the long part of the loosed belt) can be calculated with the following equation: [9]

\[ T_1 = \sigma_a \times A \]

where:  
- \( T_1 \) = tension on the tensile side (N); 
- \( \sigma_a \) = allowable belt tension (MPa); 
- \( A \) = belt cross-sectional area (m²).

Loose side tension \( T_2 \) can be calculated using the following equation:

\[ \frac{T_1 - m_s \cdot v^2}{T_2 - m_s \cdot v^2} = e^{\alpha_1/\sin 2} \]

where:  
- \( T_1 \) = tension in the loose side (N); 
- \( m_s \) = belt mass (kg); 
- \( v \) = linear velocity (m/s).

Linear velocity can be calculated using the following equation:

\[ v = \frac{2\pi \times d_m \times N}{60} \]

where:  
- \( d_m \) = pulley diameter of the drive motor (m); 
- \( N \) = pulley rotation speed (rpm).

The power per belt can be determined using the following equation [10]:

\[ P_s = (T_1 - T_2) \times v \]

where:  
- \( P_s \) = power per belt (W/belt).

The number of belts used can be calculated using the following equation:

\[ n_s = \frac{P_t}{P_s} \]

where:  
- \( n_s \) = number of belts; 
- \( P_t \) = available power (W).

c. Axle analysis: the shaft functions to channel mechanical power from one engine element to another engine element. Calculation of shaft with pure twisting load or bending twisting with axial load can be calculated using the following equation: [11]

\[ d^2 = \frac{16}{\pi^4} \left[ \left( \frac{K_m \cdot M_b}{d_o} \right)^2 + \left( K_t \cdot M_b \right)^2 \right] \]

where:  
- \( d_o \) = outer diameter of the shaft (m); 
- \( d_i \) = inner diameter of the shaft (m); 
- \( K_m \) = bending moment correction factor; 
- \( K_t \) = twisting moment correction factor; 
- \( M_b \) = bending moment.
(Nm); M = twisting moment (Nm); S = permissible shear stress (N/m²); Fa = axial force (N); α = column action factor.

d. Bearing analysis: a bearing is a machine element that supports a loaded shaft, so that the rotation or alternating motion can take place smoothly, safely, and a long time to use. The technical life of the bearing can be calculated by the following equation:
The speed factor for ball bearings (fₙ) with the following equation:
\[ fₙ = \left(\frac{23.3}{n}\right)^{1/3} \]
where n is the shaft rotation.

Bearing age factor (fₜₙ):
\[ fₜₙ = \frac{c}{w} \]
where: c = dynamic nominal load specifications (kg); w = equivalent load (kg).

Nominal age (Lₙ in million rotation)
\[ Lₙ = 500. fₘ₃ \]

e. Spi analysis: spi is used to prevent slippage in the pulley rotation. The torque moment on spi can be calculated by the following equation:
\[ Mₜₖ = (T₁ - T₂).r \]
where: Mₜₖ = torque moment (Nm); r = pulley radius (m).

The tangential force acting on the spi located on the components of the machine elements can be calculated using the following equation:
\[ Fₜₖ = \frac{Mₜₖ}{r} \]
where: Fₜₖ = tangential force (N); r = pivot radius (m).

To calculate the spi size used, the following equation applies:
\[ F = \tau a \times A \]
\[ A = \frac{F}{\tau a} \]
where: A = spi area (m²); F = force (N); τa = allowable shear stress (MPa).

In the spi shear force can occur at cross section b x l because of the force F (N), thus the spi shear stress can be calculated based on the following equation:
\[ \tau k = \frac{F}{b \times l} \]
where: \( \tau k \) = shear stress (N/m²); b = spi width (m); l = spi length (m).

Then compared with the permissible shear stress calculated using the following equation:
\[ \tau ka = \frac{\sigma}{Sf k₁ \times Sf k₂} \]
where: \( \tau ka \) = permissible shear stress (N/m²); \( \sigma \) = tensile strength of ingredients (N/m²); Sf k₁ = safety factor (generally 6); Sf k₂ = safety factor (1-1.5 for slow load, 1.5-3 for light impact, 3-5 for heavy impact).
f. Frame analysis: calculated based on deflection and permissible critical load. The load that can be supported by the line uses the following equation:

\[
\delta = \frac{PL^2}{4EI}
\]

where: \(\delta\) = allowable deflection (m); \(P\) = load acting on the frame (kg); \(L\) = row column length (m); \(E\) = modulus of frame elasticity (kg/m²); \(I\) = Moment of frame inertia (m⁴).

Then the deflection resulting from the load supported by the frame is compared with the deflection allowed using the following equation:

\[
\delta = \frac{1}{300}L
\]

where: \(L\) = row-column length (m).

3. Results and Discussion

The process of manually scraping the dough is done by human labor and requires operator skills as shown in Figure 2. The resulting product quality is quite good but requires a long time. The size of the production scale depends on market demand and the ability of labor. Worker fatigue is also a determining factor for getting a good mixture. The average production yield per day reaches 30 kg but is deemed unable to meet the demands of customers. Based on the results of a survey of market opportunities for national mackerel crackers, it is quite high, an increase of 5% from the previous year. This increase is seen from the estimated value of demand greater than the value of the supply. Thus, the mackerel crackers products are marketable, considering the value of the market share and very high market opportunities.

Applying appropriate technology with the development of a kneading machine dough machine is needed to facilitate the work of kneading dough and increase the production capacity of the resulting dough. Production capacity with manual kneading is around 30 kg/day, whereas with a dough kneader machine the kneading capacity can reach 100 kg/hour or around 800 kg/day, which means an increase in capacity of 2600%. The kneading process cannot be done just once, but it is done about 2-3 times or until the dough is smooth. This problem makes the kneading related to the ability of workers and requires a long time. So, the use of a dough kneader machine helps the production process in time efficiency.

![Figure 2. The kneading processes.](image_url)

Figure 3 shows a dough kneader machine that has been developed with a capacity of 100 kg/hour. The machine has been handed over to SMEs and has been used in the production of mackerel crackers. The kneading machine uses a kneading system that is driven using an electric motor and transmission. The engine used on this engine is a 1.5 HP electric motor, 1 phase, and has a rotational speed of 3000 rpm. The transmission system on the dough kneader machine uses pulleys and sprockets. Pulleys used on this machine are 7.62 cm in diameter with A-type v-belts.

The theoretical calculation of the shaft results in a minimum of 17 mm in diameter, while the diameter of the shaft used in the machine is 25 mm. The shaft used by this machine is suitable because the diameter is greater than the minimum diameter size. Dough kneader machine uses a 6205 ZZ NTN
type bearing. Based on theoretical calculations, the nominal bearing age of 5945.689 hours is obtained; the minimum age requirement for agricultural machinery bearings is 3000 hours so that the bearing on this dough kneader machine is suitable to be used. The screw press tube is made of stainless steel pipe with a diameter of 12.7 cm and a length of 55 cm, while the screw press has a diameter of 10 cm with a shaft of 2.54 cm. A distance of 2.7 cm is used to maximize the process of dozing the dough and avoid the buildup of dough in the middle of the tube. At the end of the dozing tube, there are discharge holes made of stainless-steel pipes which are 10 cm long and 2.54 cm in diameter. The total dimensions of the machine have a size of 125 × 50 × 145 cm. Frame height is obtained from anthropometry factors, in which from the elbow height data of men in Indonesia of 1003 mm so that the results of the overall height of the machine are obtained by 1000 mm in comparison with operator height to machine height. Deflection of the frame was by 0.000013 m.

Dough kneader machine specifications can be seen in Table 1. Dough kneader machine functional testing is carried out to see the function of the machine from the results of the design that has been made. The results of the test are obtained that the machine can work in accordance with the original purpose of being able to pulverize the dough according to a predetermined design. The capacity of the machine can reach 100 kg/hour, greater than the dozing manually done with a capacity of 30 kg/day. By using this machine, the quality of flour dough also increases in quality compared to manual kneading. Figure 4 shows the process of outputting the dough from the output pipe. The mixture is well mixed and homogeneous. To get smoother dough for good texture in mackerel cracker processing, the dozing process is repeated 2 to 3 times so that the dough becomes elastic or if pressed slightly it will return to its original form. It is intended to obtain a more compact dough quality so that the texture of the mackerel crackers is smoother compared to manual processing.
Table 1. Machine specifications

| No. | Component name | Specification |
|-----|----------------|---------------|
| 1.  | Actual capacity | 100 kg/h      |
| 2.  | Total dimensions | 125 × 50 × 145 cm |
| 3.  | Driving force   |               |
|     | Motor type      | Electric motor 1 phase |
|     | Power           | 1.5 HP        |
|     | Rotating speed  | 3000 rpm      |
| 4.  | Transmission system |         |
|     | Pulley          | ∅ = 127 mm Tipe A |
|     | Belt            | ∅ = 250 mm, p = 320 mm |
|     | Axis            | ∅ = 100 mm, t =35 mm |
|     | Gearbox         | Type 80 Ratio 1:20, gear coupling system |
| 5.  | The pads        | 6705 ZZ NTN   |
| 6.  | Dough output    | ∅ 2.54 cm    |
| 7.  | Screw           |               |
|     | Type of material | Stainless steel |
|     | Dimension       | ∅ 10 cm length 50 cm |
| 8.  | Order           |               |
|     | Iron type       | Mild steel UNP, iron plate, iron elbow |
|     | Order length    | 125 × 50 × 70 cm |

4. Conclusions
Dough kneader machine has a capacity of 100 kg/h so that it can increase the production capacity of mackerel crackers in Yuan Mina Kartika SMEs which were previously only able to produce 30 kg/day. The quality of the dough has a smooth and homogeneous structure to produce an amplified cracker product with a smooth and even texture. The efficiency of production process time increases significantly with the level of comfort of workers in the process of scraping. The efficiency of the worker was increased because they do not have to stir and press the dough repeatedly and do not feel excessive pain in the hands, shoulders, and back. By using this machine, the quality of flour dough also increases compared to manual kneading.

References
[1] Rochwulaningsing Y, Sulistiyono S T, Masruroh N N, Maulany N 2019 Marine policy basis of Indonesia as a maritime state: The importance of integrated economy Marine Pol. 108 103602 1-8.
[2] Nurkholis, Nuryadin D, Syaifuding N, Handika R, Setyobudi RH, Udjianto DW 2016 The economic of marine sector in Indonesia Aquatic Procedia. 7 181-186.
[3] Tran N, Rodriguez U P, Chan C Y, Phillips M J, Mohan C V, Henriksson P J G, Koeshendrajana S, Suri S, Hall S 2017 Indonesian aquaculture futures: An analysis of fish supply and demand in Indonesia to 2030 and role of aquaculture using the AsiaFish model Marine Pol. 79 25-32.
[4] Benjakul S, Karnjanapratum S 2018 Characteristics and nutritional value of whole wheat cracker fortified with tuna bone bio-calcium powder Food Chem. 259 181-187.
[5] Stefanus S 2005 Reverse engineering – theory and application. (Semarang: Universitas Diponegoro)
[6] Okolie P C, Chukwujike I C, Chukwuneke J L, Dara J E 2019 Design and production of a fish feed pelleting machine Heliyon 5 6 1-7.
[7] Hendrawan Y, Anta D K, Ahmad A M, Sandra S 2019 Development of fuzzy control systems in portable cultivation chambers to improve the quality of oyster mushrooms *IOP Conf. Ser.: Mater. Sci. Eng.* **546** 032013

[8] Ilyushin A A, Lensky V S 1967 Strength of material. 1st edition. (London: Pergamon Press Ltd)

[9] Childs P R N 2019 Mechanical design Engineering Handbook 2nd Edition. Elsevier Ltd.

[10] Hall A S, Holowenko A R, Laughin H G 1993 Theory and problem of machine design. (Singapore:McGraw-Hill)

[11] Khurmi R S, Gupta J K 2008 A textbook of machine design. (New Delhi: S Chand & Company Ltd)