Design of Mechanical Roasting Machine using Ergonomic Approach to Increase Productivity of Small Medium Enterprise: A Research at Opak Craftsmen in Sumedang

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Abstract. The object of this research is small and medium micro enterprises that make sticky “Opak” with a manual process. The process of ripening food by roasting, where food is placed on a ram wire that is placed on top of the fire stove. The quality of the opaque produced is very dependent on the skills of the employees and the accuracy of flipping through the opaque to obtain good results. In fact, the opaque quality of roasting results varies. Besides, limited production results, causing high demand from customers often cannot be fulfilled by the “Opak” craftsmen. To overcome this problem, the research team designed ripening of glutinous “Opak” with roller method. This sticky rice opaque machine with roller method uses electric power with a low-speed level, so the craftsmen can easily control the maturity level of food ingredients. With the making of the “Opak” sticking machine in the roller method, it is expected that the ripening process can be done with a machine and the maturity level can be uniform; so that the production process is not limited by employee skills; and customer requests can be met.

Keywords: Roasting, Applied Technology, Ergonomics, Optimization

1. Introduction

Small industries are often seen as a backward part of the economic structure, considered unable to be expected to make a meaningful contribution to economic growth and need to get help for a sense of social justice. This view is not always approved by many parties. But some people consider the small industry as an absolute part that must exist in a healthy economic structure. Until today, most of the industries are still implementing the conventional process to produce their product. One of these is still depends on the skill of its employee.

Opak is one of the traditional foods in West Java that is quite popular. This food is usually consumed as a snack or "snack" food type of crackers. The main raw material in making this opaque is glutinous rice while other commonly used ingredients are coconut milk. Opak is made by baking on coals. Glutinous rice that has been soaked overnight is cooked until it becomes rice after it is mixed with coconut milk and spices [1].

The need for a wide area as a place of drying. Spacious of drying land owned by a small-medium enterprise (SME) can also affect the amount of product that can be produced. If a small-medium enterprise (SME) has a wide area as a place of drying, more products can be dried and produced, and vice versa. So, when the market demand for the product has increased, small medium enterprise (SME) needs to consider a wide area of drying, the amount of product to be dried, and the length of time for
drying the product until it is completely dry. It would be very unfortunate if a large market opportunity cannot be fulfilled by the small medium enterprise (SME) because of the limited area of drying. [2].

![Diagram of the stages of creating “Opak Ketan” at Opak Craftsmen]

**Figure 1.** The Stages of creating “Opak Ketan” at Opak Craftsmen

This research focused on the roasting process. In the roasting process, a drying technique with a temperature of 100°C - 120°C which is fuelled by firewood or charcoal is required. In the existing process, the roasting process is done by the manual technique by three to five workers at a time. The stove was made of dry clay, that box-shaped or round-shaped filled by charcoal/firewood. The process for roasting may take 10 – 15 minutes of roasting to make the opaque at a good level of baked. The criteria of a well baked opaque can be seen in the color of the opaque result. The color of the good level of baked is yellow-brownish.

![Image of traditional process of roasting]

**Figure 2.** Traditional Process of Roasting

In each roasting workstation, one worker only gets about 100 pieces of baked opaque, that need 10 – 15 minutes processing time.

2. **Methods**

2.1. **Productivity**

Productivity, in general, is the ratio between the inputs used with the output produced. One of the steps taken by a company in order to improve its productivity is by making improvements of tools (technology) or by increasing human resources.
2.2. Ergonomic

Ergonomics is a science that studies and examines the limitations and advantages of humans, then the information obtained will be used to design products, machinery, facilities, environment, and work system. The main objective of an ergonomic application is the application of good aspects of health, safety, and working comfort to achieve a good quality of work. At a higher level of ergonomics aims to create optimal working conditions. Ergonomics and K3 (Occupational Safety and Health) are two things that cannot be separated because they have the same goal that is in improving the quality of work [3].

The definition of ergonomics can be described in a focusing, objectives, and the approach of ergonomics where the explanation is mentioned as follows [4]:

1. Ergonomics focuses on human interactions with the product, equipment, facilities, procedures, and environments where human daily life and work.
2. The goal of ergonomics is to increase the effectiveness and efficiency, improved safety, reduced fatigue, and so on.
3. Ergonomics approach is the application of information about human limitations, capabilities, behavior characteristics and motivation to design procedures and the environment in which human activity daily.

2.3. Product Development Stage

A product is a thing which can be sold by a company for a customer to fulfil their needs. Product development is a set of activity, begin from perception analysis, then end with production, selling, and distribution. The product development process generally comprises the steps of an early-stage or often also referred to as phases. According to [5] in his book, general product development process consists of 6 phases, these are:

- **Planning Phase**
  The planning phase is an activity called 'zero phase' because this activity precedes the approval of the project and the process of launching the actual product development.

- **Product Development Process**
  In the development phase, we have to identify the target market, market needs, and concept alternative and evaluate the chosen concept for future development. This concept is a description of shape, function, and design product, and it consists of product specification, product analysis, competitor analysis, and economic project analysis.

- **System Level Design**
  In this phase, we are defining the product architecture and detail product become a subsystem and component. The outputs for this phase are product shape, a functional specification from every subsystem, then flow diagram to define the ending of the process.

- **Detail Design**
Detail design phase includes full specifications of shape, material, and tolerance of all component units of the product and identification of all standard components purchased from suppliers. Otherwise, the process plan and equipment designed for each component are made, in the production system. The output of this phase is to control the recording of the products, images for each component of the product and production equipment, the specification of components that can be purchased, as well as plans for the manufacture and assembly of products

- Testing and Refinement
  In this phase of testing will be conducted to test the components of critical components such as material test of endurance.

- Production Ramp-up
  At this stage, the product was launched on a small scale in order to get feedback. A product is usually presented in the company's internal scale as input for further evaluation.

2.4. Conceptual Model
This research designs a roasting machine that will be used to roast/bake opaque using ergonomic approach. To design the machine, the first thing to do is to identify the activity of roasting opaque with the existing technique and to identify what the complaints are often experienced by the workers. After that will be analyzed regarding ergonomic and create design. The results of the roasting machine design will then be made technical drawings to know the dimensions in each part.

![Figure 4. Conceptual Model of Research](image)

3. Result and Discussion

3.1 Identifying Needs Statement
In the stage of identifying needs statement will be done by direct interview with the workers and the craftsmen owner. So, we get the results recapitulation needs statement as follows.

| No. | Needs Statement                                           |
|-----|----------------------------------------------------------|
| 1   | The product has a maximum carrying capacity.             |
| 2   | The product is safe when in use.                         |
| 3   | Products can reduce the workload of workers and reduce the risk of work accident. |
| 4   | The product has a comfortable size when in use.         |
| 5   | The product has an ergonomic design.                     |
| 6   | The product can minimize the number of required operators.|
| 7   | The product has tools.                                   |
3.2 Create the design

In the design process, we interpret from the needs statement into the design stage. We create the roasting machine design into several parts:

1. Main frame
   The main frame is the basic frame for the machine. In this frame, all another part will be attached, using bolt and nuts. The dimensions of this part are measured based on anthropometrics from average Indonesia people. The height of the main frame only a half from the average height of adult people in Asia which around 162 cm [6]. So, the dimensions of the main frame are 85 cm, 125 cm width, and 200 cm of length.

2. Hexagonal-shaped roller frame
   The hexagonal-shaped roller frame will replace the existing main process of roasting: roasting and flipping the opaque. The hexagonal-shaped are considered as the best fit shaped to make the opaque can flipped by itself while get baked. This will reduce the dependency on worker accuracy and speed during the flipping process.

3. Move-able charcoal stove
   To reduce the use of drying/roasting area, we design that the charcoal stove is attached below the main frame, and it is adjustable depends on the function. If it needs to remove or change the charcoal, the worker can easily slide the stove outside. When the workers need to roast the opaque, then they can slide in the stove back again.

4. Puller stick
   The puller stick is stuck in the stove using bolts, so the workers not exposed to heat from the grill. The long of the puller stick can be customized based on the requirement. In this case, we design the length of the stick around 75 cm.

| No | Item                          | Height  | Width | Long  |
|----|-------------------------------|---------|-------|-------|
| 1  | Main frame                    | 85 cm   | 125 cm| 200 cm|
| 2  | Hexagonal-shaped frame         | 50 cm (diameter) | 100 cm | -     |
| 3  | Move-able charcoal stove       | 30 cm   | 100 cm| 120 cm|
| 4  | Puller stick                  | -       | -     | 75 cm |

After obtaining the desired final specification, then we made the roasting machine design. The following is the result of the mechanical roasting machine design.

![Figure 5. The Design of Mechanical Roasting Machine](image-url)
3.3 Create the Prototype

After the design process is approved, we create the mechanical roasting machine prototypes on local iron craftsmen, so that the workers and the owner can evaluate that the use of the roasting machine improved their productivity. Before using the machine, each worker will be baked approximately 10-15 minutes for 100 pieces of opaque, and they have to continuously and manually flip the opaque. After using the machine, one worker can bake about 200-300 pieces of opaque, without continuously and manually flipping the opaque to get the good level of baked opaque.

![Image](image.png)

**Figure 6.** The Final Assembly of Mechanical Roasting Machine

A comparison results of production before and after using the roasting-machine can be seen in Table below.

| Variable     | Before using machine | After using machine          |
|--------------|-----------------------|------------------------------|
| Time         | 10 - 15 minutes       | 10 – 15 minutes              |
| Capacity     | 100 pcs/stove         | 250 – 300 pcs/stove          |
| Flipping method | Manual by worker       | Auto flipping by the        |
|              |                        | hexagonal-shaped frame      |
| Charcoal stove | Static stove           | Moveable stove              |

Based on the data above, the productivity level is increased, because the craftsmen can produce more quantity in the same production time. At the consideration, the other workers need to improve their skill to operate the machine.

4. Conclusion

Based on the results of data processing and analysis, then obtained some conclusions that can solve the problems in this study. Here is the conclusion that has been obtained.

1. The product of the mechanical roasting machine can meet the objectives of the research that can design a product that can improve work productivity by applying the concept of ergonomics in the process of designing.
2. In designing the mechanical roasting machine, the material which will be applied to the product is steel plate for the platform, frame, move-able stove, the wire mesh for the hexagonal-shaped frame, and iron pipe rod/iron stick for the puller stick.
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