# Development of Boiling Stove for *Lekor* Ball's Production; Local Industries (SME)

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**ABSTRAK**

*Small and medium-sized enterprises (SMEs) have been expanded widely and play an important role in breeding Malaysian economy. Maja Baroh Enterprise is one of the SMEs in 'keropok lekor' industries which facing a problem with their production capacity. Due to high demand in the market, the owner ought to increase their production. 'Keropok lekor' or lekor ball is the most authentic and evergreen favourable snack in Malaysia. The main purpose of this study is to design, fabricate and testing boiling stove for easy boiling mechanism that can uphold the current demand of lekor ball. The boiling process is very crucial in lekor ball production. Thus, the new improved boiling stove that can fit into the new shop floor layout is designed. To achieve this objective, several concepts design has been intended for selection through Pugh Decision Matrix and Finite Element Analysis via Pro Engineer Wildlife 5.0 or Creo. After the selection process, the preferable design is carried forward for the next process which is detail drawing. The detail drawing is created prior to fabrication process using software application Catia V5. Then, the fabricated prototype of boiling stove is tested to run on production floor. To determine the effectiveness of the new improved and customize boiling stove, the time for boiling process to complete for before and after the implementation of the boiling stove is taken and analysed. As a result, the implementation of boiling stove is a good start for Maja Baroh Enterprise to increase their production capacity up to the range of 200 kg to 250 kg per day since the percentage improvement in efficiency is 87.5 %.*

**Keywords:** Boiling stove, improvement, SME's, lekor ball

## INTRODUCTION

Small and medium-sized enterprises (SMEs) play a significant role in breeding Malaysian economy currently. '*Keropok lekor*' or *lekor* ball is one thriving industry that has long existed since it was sold as a small business. It is important for SMEs to acquire innovation or mechanization in order to increase productivity and withstand the market demand in the future [1] [2]. Maja Baroh Enterprise which is one of the SMEs company that shifting from conventional process of making '*keropok lekor*' into lean manufacturing system so that they can increase their productivity in order to fulfill the increasing trend in market demand as well as to get high return. In this changing phase, few of the existing machine or equipment needs to be replaced to adapt into lean manufacturing system or new layout to speed up the processes and increase the productivity of *lekor* ball. Five machines and equipment involved in the production of *lekor* ball which are mixer machine, boiling pot, industrial fan, forming machine, and vacuum seal machine. This production needs to change their method in production floor so that they can increase the production size as well as to keep the business competitive and profitable. The change of the process layout is a must and major process involved in this industry should undergo some modification [3]. The first phase in changing process, the company has managed to get the conveyor to be placed at the boiling station. Formerly, worker must manually put the *lekor* ball into container and manual handling to cooling and drying station after boiling process. Thus, the invention of boiling stove is the main concern since it is one of the crucial processes in making *lekor* ball.

The objectives of this research paper are as following:

a) To analyse the current boiling stove.
b) To design, fabricate and testing boiling stove for easy boiling mechanism that can uphold the current demand of *lekor* ball.
c) To optimize the boiling stove parameters.

The limitations of this research paper are as follows:

a) Volume Capacity (up to 50 kg at one time) must consider the capacity of existing mixer which is 25 kg per run. Thus, the capacity of new improved boiling pot is estimated to double the mixer capacity because the boiling process will result the *lekor* ball to expand due the presence of water.
b) Dimension of the newly improved boiling pot is preferably open type rectangular so that it is easier to put under forming machine.
c) Fit to existing conveyor width (279.4 mm); the newly improved boiling pot must have one side that can easily attach to the existing stack conveyor running on the shop floor.

## LITERATURE REVIEW

The design process of engineering is a series of actions that guide engineering teams in dealing with problems and it is sequential, which ensures that the design steps can be replicated as many times as necessary, making improvements along the way when facing error and revealing new design options to find viable solutions [4]. According to Khandani [5], engineering design is the creative process of translating abstract ideas into tangible objects (products or systems) to fulfill human needs that differ from painters, authors, or sculptors. Design is a creative activity, and [6] believed engineering design that undertaken by engineer begin with a specific objectives or customer requirement by developing and evaluating possible design up to the best way in achieving that objective. In the meantime, SMEs in Malaysia can be divided into three categories namely the Micro, Small, and Medium Enterprises. The variables used to define SMEs can be varies upon industries; include the total number of employees, assets, turnover, capital and investment (Kushnir, 2010 as cited in [7]).

### ***Keropok Lekor*** **Industry**

*'Keropok lekor'* are made from simple local ingredients such as fish meat, starch, salt, and preservative [8]. There are several processes involved in order to produce *'keropok lekor'* as fish meat shredding, mixing ingredient, kneading the dough, boiling, cooling and cutting and dried [9]. However, the steps in making *'keropok lekor'* is varies depend on the maker's creativity [10]. The traditional method of preparing *'keropok lekor'* still implemented by some small business manufactures at certain area in Malaysia. The scarce of technology and information resulted very low productivity thus leave the market demand unfulfilled. '*Keropok lekor*' is precooked by boiling in water right after the cutting process. Conventionally, the water is heated up to boiling point (100 °C) during the boiling process using firewood because it is a believed that it will give a good flavour and an authentic fragrance to the '*keropok lekor*' [11]. The traditional boiling process of '*keropok lekor*' is by heating up the water using firewood. This method is not very efficient where it is difficult to control the fire and it also produces smoke and ash to the surroundings [9], [12],

[13]. Firewood known for most widely used domestic fuel and can be used in a long period because of its coal and also it is cheaper than gas stove [14].

## Boiling Stove

The boiling stove that has been used in '*keropok lekor*' industries especially in Maja Baroh Enterprise is a typical household pot but with larger diameter as shown in Figure 1. The diameter of the pot is 762 millimetres. The employees need to use two large boiling pots per shift to cater the *lekor* ball production. The workers manually put the *lekor* ball into the pot that contain boiled water, and manually scoop it up onto the container once it done boiled (estimated after 20 - 30 minutes) for the next process which is cooling and drying.

Whilst another *'keropok lekor'* maker known as Kamilah Mutiara located in Pekan, Pahang has been used the typical boiling pot with firewood as fuel in making *'keropok lekor'*. However, in these recent years Kamilah Mutiara receives a fund from Fisheries Development Authority of Malaysia in a form of big and modern machine to help boosting the productivity of *'keropok lekor'*. Kamilah Mutiara was capable to produce three tons of *'keropok lekor'* on monthly basis with the assistance of the machine.

**Figure 1.** Current boiling stove used in Maja Baroh Enterprise.

## Pugh Method

Pugh method is one of the useful tools that can be used to evaluate the most suitable concept at the concept stage. Invented by Stuart Pugh the decision-matrix method or Pugh method or Pugh Concept Selection is a quantitative technique used to rank the multidimensional options of an option set. It is frequently used in engineering for making design decisions but can also be used to rank investment options, vendor options, product options or any other set of multidimensional entities. A basic decision matrix consists of establishing a set of criteria upon which the potential options can be decomposed, scored, and summed to gain a total score which can then be ranked. Importantly, the criteria are not weighted to allow a quick selection process. The advantage of this approach to decision making is that subjective opinions about one alternative versus another can be made more objective. Another advantage of this method is that sensitivity studies can be performed. An example of this might be to see how much your opinion would have to change in order for a lower ranked alternative to out rank a competing alternative.

This method compares each concept relative to a reference or datum concept and for each criterion determines whether the concept is superior, worse, or similar level as reference concept [15]. There has been a study on Pugh Controlled Convergence Method to evaluate its relationship to recent developments in design theory. Computer executable models are proposed simulating a team of people involved in iterated cycles of evaluation, ideation, and investigation. It is an effective method to apply during the concept design phase, mostly because it encourages an interplay of evaluation and ideation [16]. Pugh's method helps to clarify the existence of relationships between customer attributes and engineering design decisions, however they provide only a qualitative rather than quantitative assessment of these relationships. Designers can use QFD and Pugh's methods to elicit, organize and record end-user or customer preferences, and then they can incorporate them into their design decisions [17].

## Existing Product Comparison

Many types of boiling stove that available in the market. However, only five best relevant products are compiling for comparison as per shown in Table 1.

**Table 1** The Comparison of Existing Products That Available in the Market

| Product | Description |
|---|---|
| **Gatto Tilt Pans**  | • Stainless Steel Tilt Pan Gas-80L<br>• Model TP2SG<br>• Dimension 1400X950X900mm<br>• Capacity 80 L<br>• Weight 370 kg<br>• Btu 140000<br>• 304 S/S inner pan, mild steel machine and base<br>• Ideal for stews, soup, rice and etc. |
| **Electric Braising Pan / Commercial**  | • The pan body of type 304 stainless steel, solid one-piece welded heavy duty construction<br>• All exposed surfaces shall be of stainless steel with an all stainless steel base<br>• The cooking surface heavy 3/8 thick stainless steel clad plate, fitted with clamped-on electric heating elements, ensuring efficient heat transfer over the entire cooking surface<br>• Heating elements contained within the pan body<br>• Thermostat, contractor, other electrical components and indicator light installed and mounted in stainless steel, drip-proof console housing |
| **Oil Jacketed Boiling Pots**  | • Oil Jacketed Boiling Pot- Gas 135L<br>• Model BPG135<br>• Dimensions mm D1100 X H1100<br>• Capacity 135L<br>• BTU 70000<br>• Flame failure protection<br>• Imported Italian burners<br>• Thermostatically controlled |

| | |
|---|---|
| **Buffalo Bain Marie Without Pans Pot Cookware Commercial Electric**<br> | • Quality stainless steel construction<br>• Wet heat only operation<br>• Takes containers up to 150mm deep<br>• Pans and divider bars sold separately<br>• Dimensions 270(H) x 340(W) x 615(D)mm<br>• Specifications for this item<br>• Item shape rectangular<br>• Item Weight 8.0 kilograms<br>• Length 61.5 centimetres<br>• Wattage 1.3 kilowatts |
| **Square Type Kitchen Pot Earnest**<br> | • Size 300mm<br>• Capacity 25L<br>• Inside Dimension 300x300x300mm<br>• This product is manufactured in Japanese standards |

## Stainless Steel (SST)

Stainless steel is broadly used in food manufacturing for many good reasons. It is formulated by the addition of at least 10.5% of chromium from total composition. One of the characteristics of chromium is highly reactive to oxygen and rapidly able to forms a strong inactive barrier on its outer surface that highly resilient and can protects internal structures from further corrosion [18]. Recorded not more than 10 types of stainless steel are used for storage, production, transportation and catering of food and beverages [18]. However, only two types of stainless steel are most used in food manufacturing industries which are 304 and 316. Both 304 and 316 stainless steels are austenitic, which means they are extremely strong and easy to fabricate. However, 304 Stainless is the most widely used because of its lesser cost and has following physical properties:

- Density: 8.03g/cm
- Electrical resistivity: 72 microhm-cm (20C)
- Specific Heat: 500 J/kg °K (0-100°C)
- Thermal conductivity: 16.3 W/m-k (100°C)
- Modulus of Elasticity (MPa): 193 x 103 in tension
- Melting Range: 2550-2650°F (1399-1454°C)

## METHODOLOGY

The research methodology use is direct data collection method. In order to access all the information needed in this study, the data are collected and recorded by interview, observation and document reviews. Observation method involved site visit to Maja Baroh Enterprise. This observation includes researching, viewing and understanding the actual condition and problem that arise in *lekor* ball boiling process. The interview method was made through meeting with few notable people in *'keropok lekor'* industries. The survey method is the best data collection technique as it enables us to gather a larger amount of data and information from target respondents within a short period of time. Also, from interview, we can identify the customer requirement and investigates the current boiling process flow. After that, the modelling of the new design of boiling stove will be sketches by using CAD software. This is preliminary studies which examine the potential of designing a new boiling stove. The data analysis will be based on secondary data, observation and interview. The secondary data includes a list existing design of boiling stove in the market, the boiling stove that has been used by '*keropok lekor*' manufacturer, and also previous studies done in designing the boiling stove. In this project, the observation was done by workers where the time taken for boiling process to complete is documented in a given table. The data is recorded in table with the aid of computer-assisted electronic stopwatch, camera video and cell phone. Finite Element Analysis and Pugh Method is used as a method for concept selection. The terminology of work and planning for this research was shown in the Figure 2.

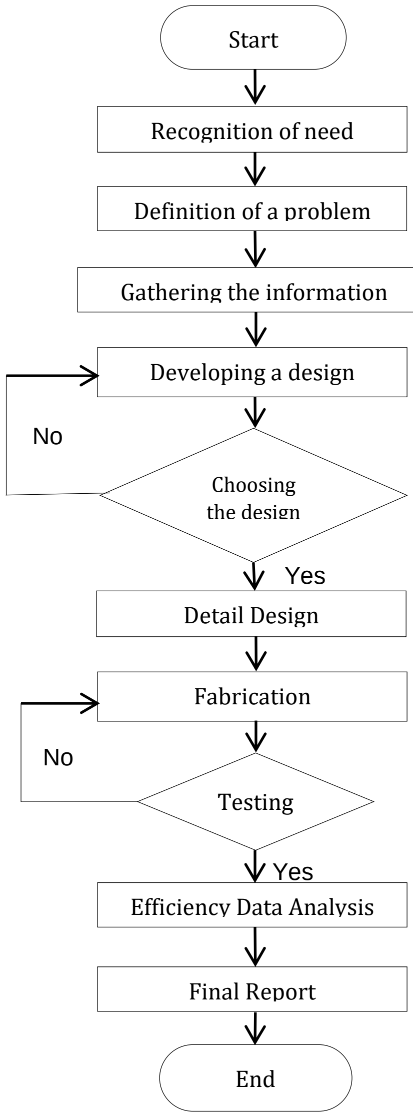



**Figure 2.** Methodology flow chart for boiling stove design.

## Finite Element Analysis (FEA)

Creo Simulate permits the simulation of thermal conditions. A steady state thermal analysis calculates effects of constant thermal loads on a model and is used to determine temperatures, heat flow rates, and the heat fluxes in a part. A steady state analysis is often a pioneer to a transient thermal analysis to determine the initial conditions. Transient thermal analysis, the most common form of thermal analysis, determines the temperature, heat storage and other thermal quantities in a model due to a time varying load. The important of FEA in this project is to do the comparison for the concept selection. Through Mechanica Simulation in Creo, it can provide easy methods to visualize results of analysis computations.

**Concept Selection**

Pugh method is used to perform the evaluation by determine scoring the technical requirements each concept as superior or inferior in comparison to a reference datum design. The technical priorities or selected criteria will be assigned to the Pugh matrix and the boiling stove design with the highest total score is selected in order to be carry forward for next design step.

**The Pugh Evaluation Process**

a) Choose the criteria by which the concepts will be evaluated.
b) Formulate the decision matrix - The criteria fill the row headings of the matrix, and the concepts fill the column headings.
c) Clarify the design concepts.
d) Choose the benchmark or initial datum concept.
e) Run the matrix.
f) Evaluate the ratings.
g) Establish a new datum and rerun the matrix if necessary.

**Finalize Design of the Selected Concept**

The strongest concept or set of concepts that resulted from the Pugh decision matrix promoted for further development. In this section, the preferred sketch diagram is going to be transferred and portrayed in CAD working drawings using CATIA V5 prior to fabrication process. The selected concept is chosen due to its favourable design. It has the features that exceed the function of other design concept. The CAD software that has been choosing in this project is CATIA V5 because it is the design leading software for product 3D CAD design excellence. It is used to design, simulate, analyse, and manufacture products in a variety of industries including aerospace, automotive, consumer goods, and industrial machinery and others. It addresses all manufacturing organizations through their supply chains, to small independent producers. CATIA is increasingly chosen as the primary 3D design system for many companies as CATIA is equipped with the most versatile design tool that's applied in most industries.

There are eight parts involved in designing the boiling stove. The parts are drawing in separate sheet and then, the parts are assembling into one complete product. The parts details as per following:

a) The body of the boiling stove – consist of the main part or the body of the boiling stove
b) Stove holder – the additional part attached to main body as stove holder.
c) Chute – The most important part in this design; it is one of the design requirements so that the boiling stove cam connect to the stack conveyor.
d) Upper stand – Function as the leg for the boiling stove.
e) Adjustable lower stand – This is insert leg with adjustable function so that the height of the boiling stove can be set at desirable height.
f) Thrust – Act as a stand to support stove holder.
g) Hinges – It has the function to connect chute to the main body.
h) Centre hinges – To complete the function on hinges.

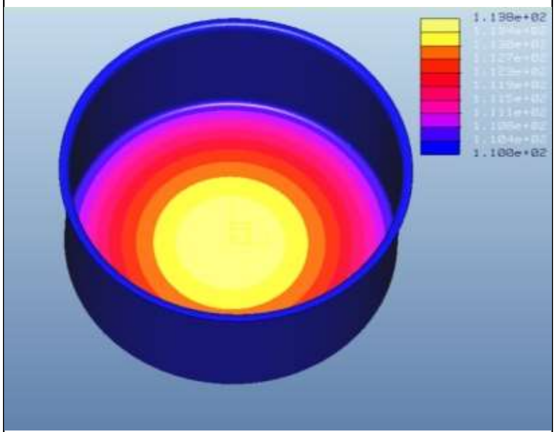
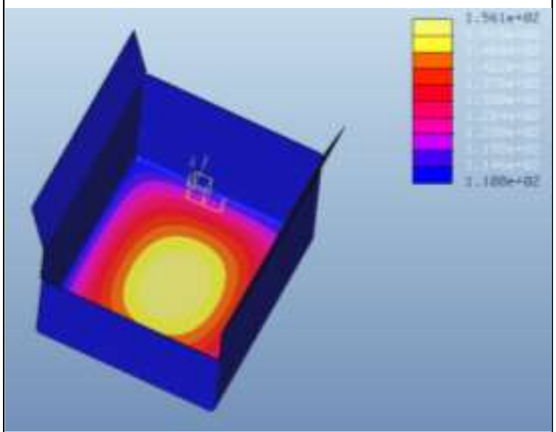
## RESULTS AND DISCUSSIONS

The explanation of the result obtained were followed the steps that being discussed in the project methodology. The result is comparing the time and the production volume gain before and after the implementation of the boiling stove in the process floor. The data were obtained from the company for 3 months before and 3 months after the implementation of the boiling stove.

### Design Analysis

The analysis of thermal using Creo Simulate on the datum and four concepts are simplified in Table 2 The table shows the detail description on steady-state or transient thermal response on each concept for comparison for concept selection. Using the thermal analysis workbench, the maximum and minimum temperature values are identified. Conduction is the transfer of heat through solids.

**Table 2** Thermal Analysis on Datum and Concepts 4 using Creo Simulation

| Idea | Thermal Analysis | Description |
|---|---|---|
| 1 | Datum  | To analyse the thermal dissipation<br>• The yellow colour shows the maximum temperature value which is 113.8°C and the blue colour shows the minimum value which is 1.10 °C.<br>• The heat distribution in aluminium is more effective than stainless steel because of its higher thermal conductivity; thus, the core temperature shows lower value as heat is distributed faster to its surrounding. |
| 2 | Concept 4  | To analyse thermal dissipation<br>• The yellow colour shows the maximum temperature value which is 156.1 °C and the blue colour shows the minimum value which is 110 °C.<br>• The heat distribution in stainless steel is less effective than aluminium because of its lower thermal conductivity. The temperature value is high compare to the datum design because of the lower heat distribution rate of the stainless steel. |

## Pugh Matrix Evaluation Process

The result of Pugh Matrix evaluation process is reflected on Table 2. There are four concept generated for selection as shown in Figure 3, 4, 5 and 6. The table shows that the strongest concept or set of concepts that favourable for further development is Concept 4. The Concept 4 design, score the highest mark and consider as superior design with 3 mark, followed by design of Concept 2 with score 1 mark. And, Concept 1 and 3 score -2 marks respectively. The design Concept 4 is prominent due to its big capacity to boil the lekor ball. It has the capacity of 318.56 L which is bigger than current boiling pot with 228L (datum). The presence of chute in order to channel the lekor ball to stack conveyor is a vital requirement in this design, and the material; as it is made from food grade stainless steel (US 304), and it has high aesthetic value - the aesthetics are usually accomplished by the shape, texture, colour, type of material, symmetry and simplicity of the repeated pattern used in the design. The design shape of Concept 4 which is similar to cuboid shape is the most preferable design because it can easily fit into the new lean layout.

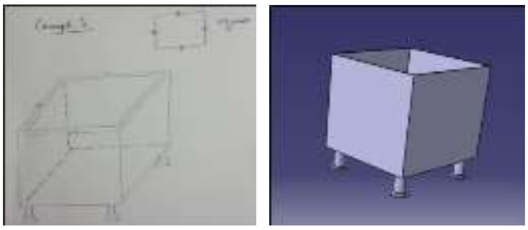


**Figure 3.** Concept 1.

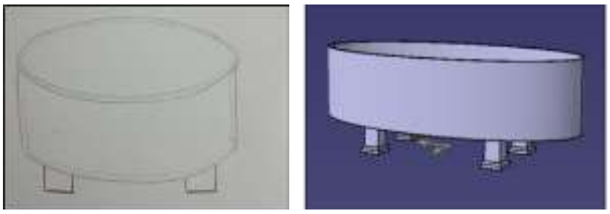


**Figure 4.** Concept 1.

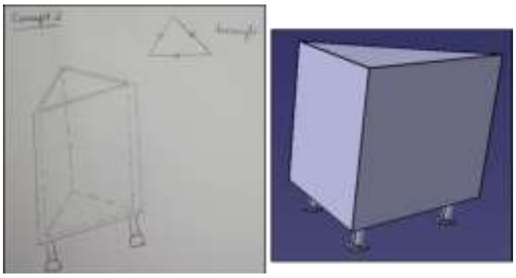


**Figure 5.** Concept 3.

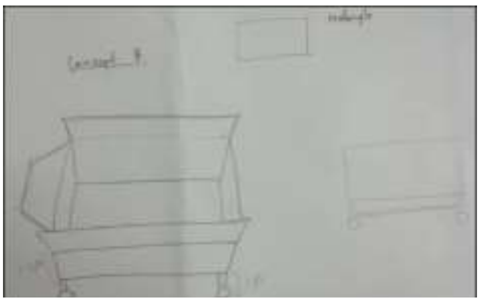


**Figure 6.** Concept 4.

As for Concept 2 as shown in Figure 4 score 2 marks because it has bigger capacity compare to the datum. The intended capacity for this design is approximately 400 L. It also uses similar material as Concept 4 which is stainless steel and it has high aesthetic value. However, concept 2 is likely very hard to connected to chute because of its longitudinal design. As for Concept 1, with score of -1 because of it has capacity which is smaller than datum which is 125 L. The installation of chute is possible but the capacity is really matter. The proposed material is aluminium which is similar to the datum. This concept has high aesthetic value compare to datum. Concept 3 is at lowest rank because of its capacity which is lower than datum which is 225 L, it has no chute as connector to conveyor. The proposed material is aluminium which similar to the datum. This concept has low aesthetic value compare to datum.

**Table 3** The Pugh Decision Matrix Evaluation Table

| | | Alternatives | | | | | |
|---|---|---|---|---|---|---|---|
| **Criteria** | **Datum** | Concept 1 | Concept 2 | Concept 3 | Concept 4 | Totals | Rank |
| Capacity | 0 | – | + | – | + | 0 | 7 |
| Chute | 0 | – | – | – | + | -2 | 8 |
| Material | 0 | 0 | + | 0 | + | 2 | 2 |
| Aesthetic Value | 0 | + | + | 0 | + | 3 | 1 |
| Thermal Analysis | 0 | – | – | 0 | – | -3 | 9 |
| | Totals | -2 | 1 | -2 | 3 | | |
| | Rank | 4 | 2 | 3 | 1 | | |

After went through the evaluation process, the preference result of the design is prepared for further development which is details drawing. The final assembly drawing which represents the components of boiling stove in one complete product as shown in Figure 7.


**Figure 7.** The isometric view of boiling stove.

### Efficiency of New Boiling Stove

As stated in Table 4, new boiling process improves by 87.5% from previous boiling process. The efficiency of improved boiling process is approximately twice previous boiling process which is 250%; previous boiling process is 133.3%. This is proved by increment in daily production capacity in Maja Baroh Ent. Previously this shop floor can only run 25 kg production per hours. After the production flow improvement by implementing lean approach with new customized boiling stove and stack conveyor, the production can reach up to 200 kg to 250 kg per day for 6 hours.

**Table 4** Results of Boiling Process Efficiency Improvement

| Description | Boiling Process Duration (min) | Efficiency (%) |
|---|---|---|
| Previous Boiling Process | 15 | 133.33 |
| Improved Boiling Process | 8 | 250 |
| Percentage improvement | 87.5 | |

## CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the research objectives have been accomplished. The first objective which is to analyse the current boiling stove is also achievable through Pugh Decision Matrix. The capacity and material of the current boiling stove has been identified in comparable to other design concept. The favourable design must exceed the current boiling stove standard.

The second research objectives which is to design, fabricate and testing boiling stove for easy boiling mechanism that can uphold the current demand of *lekor* ball is fully attainable by doing the concept selection through Pugh Matrix and Finite Element Analysis. By using Pro Engineer Wildlife 5.0 or Creo, Finite Element Analysis relating thermal distribution is identified and becoming one of the criteria in Pugh Evaluation Matrix. Then, by using Pugh Matrix Decision Method, few ideas or concept design are generated, then the generated ideas or concepts is considered through the matrix. At that point, the selected design is continued for detail drawing using Catia V5. The analysis of the testing and the efficiency of the boiling stove have been discussed. The current demand of *lekor* ball can be fulfilled as the efficiency percentage of current boiling process is improved by 87.5% from the previous boiling process. The production capacity before improvement is only 100 kg production per day. But, after the implementation of new customized and improved boiling stove, the production capacity rises up to range of 200 kg to 250 kg per day for 6 hours.

The third objective which is to optimize parameters for the boiling stove is also attainable through Finite Element Analysis where the heat distribution of was identified. The factors that affected the rate of heat flow include the conductivity of the material, temperature difference across the material, thickness of the material, and area of the material.

For future research it is recommended:

a) To design a boiling stove with non-sticky features.
b) Conduct similar study in other SMEs that involved in *'keropok lekor'* production.
c) Using other evaluation method in engineering design such as House of Quality and others.
d) Researcher could help and guide any potential SMEs to develop the equipment or machines that can enhance their productivity as well as expedite the processes so that they can expand their market globally.

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