Design, fabrication and thermal evaluation of *lemang* (rice bamboo) cooking device integrated with continuous rotating system

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Abstract: *Lemang* is one of the typical Malay foods made from white glutinous rice and is cooked inside a bamboo stalk cavity using a direct open fire method. An existing cooking technique is still using manual methods especially for turning the bamboo, so it becomes harmful for hand. This research aims to design, fabricate, and evaluate a *lemang* rice cooking device integrated with a continuous rotating system. Analysis of the design had been carried out based on considerations of design alternatives, then the static load simulation was carried out using finite element analysis to obtain a robust device design that is ready for manufacture. The overall dimension of the device is 2140 mm× 920 mm × 980 mm with a cooking capacity of 36 *lemang* per batch and has a bamboo *lemang* speed of 15 rpm which is powered by a 0.5 hp electric motor. The new design of *lemang* cooking device has been manufactured by considering important parameters based on the requirement of the *lemang* producer i.e., still using bamboo due to the typical characteristic of *lemang* cooking and still using open fire cooking method due to the availability of biomass fuel. Performance test and evaluation of the cooking device has been carried out for observing heat distribution in bamboo using ANOVA. The result revealed that there was no significant temperature difference between all positions of the bamboo surface ($p > 0.05$) during the cooking process (fairly uniform) as the impact of using a continuous rotating system. Furthermore, the specific energy consumption was also evaluated with the result of 145.72 MJ kg^{-1} dry glutinous rice, and the cooking time was 2 hours. By using a continuous rotating system, the risk of hand burning and the overcook bottom-part of *lemang* can be reduced.

Keywords: bamboo, cooking device, design, *lemang* glutinous rice, rotating system.

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1 Introduction

Lemang glutinous rice or rice bamboo is one of the typical Malay food that can be found in Indonesia, Malaysia, Brunei Darussalam, and Thailand (Wahyudi et al., 2017; Yovani, 2019). In Indonesia, Malaysia and Brunei, it is generally called *lemang* or *lamang*, but in Thailand is called as *Khao lham* (Yovani, 2019). *Lemang* is made from white glutinous rice mixed with coconut milk and is cooked inside a bamboo stalk cavity using direct open fire (Wahyudi et al., 2017; Yovani, 2019). Many *lemang* can be found in several religious ceremonials and also cultural events, but currently, in some places, *lemang* becomes a source of income for several people so that *lemang* can be found every time.

This kind of food is called *lemang* due to have a typical characteristic which is using bamboo in the cooking process, so it can't be changed with other materials. Bamboo stalk with a length varied from 500 mm

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to 700 mm is commonly used for *lemang*. Each bamboo stalk has an opening to add ingredients. The inside surfaces of the bamboo stalk are coated with banana leaves. According to Wahyudi et al. (2017), a young banana leaf is preferred for *lemang*. A few sheets of banana leaf are put inside the bamboo stalk, and ingredients (glutinous rice, salt, and coconut milk) are added until about 75% of the length. The use of bamboo, banana leaf, and coconut milk for cooking *lemang* with optimal temperature will result in specialty and pleasant aroma (Sinaga et al., 2016; Yovani, 2019).

An existing cooking technique is still using manual methods, especially for turning the bamboo, so it becomes harmful for hand. The majority of *lemang* producers are using simple tools and methods for cooking *lemang*. Besides, workers usually pay less attention in terms of safety working, such as hand burning risk. The current method of cooking *lemang* is by cooking it on the table or on the ground (Figure 1). Burning tables are made from steel with a wooden frame or made using concrete bricks. Bamboo supporting steel is mounted transversely along with the combustion table. It serves to hold on the bamboo during the cooking process. Moreover, the steel has a function to position the bamboo so it will not be falling, and the bamboo surface also exposed more heat. In the initial cooking stage, the bamboo is set about 50^o to 70^o of tilt to keep the glutinous rice dan coconut milk not to spill and increase the heat received by the upper and lower position of the bamboo surface. At the end of the cooking stage, the tilt is changed about 10^o to 20^o to make sure that the upper *lemang* is also well-cook. While cooking *lemang*, the bamboo must be rotated periodically to cook evenly. Bamboo rotating is conducted by using hand for each bamboo *lemang*. The indicator of the cooked *lemang* is the bamboo turns yellow and the bubbles stop (about 3 hours using traditional methods). At that time, the heat should be reduced and the bamboo is allowed to rest (Rasyid, 2004). The bamboo is placed near an open fire. Cooking *lemang* requires a big flame and thus plenty of fuel (firewood, coconut shells and other biomass waste).

Hussain et al. (2009) developed a new mold made of stainless steel, and it was reported that the cooking time of *lemang* was reduced about 55 minutes. Besides, some parameters such as taste, aroma, color, and compactness can be maintained (Hussain et al., 2009). Hussain and Hamidon (2011) designed a *lemang* oven and simulated it using computional fluid dinamic. It was reported that the bottom part of *lemang* receives greater amount of energy so that it was become overcooked (Hussain and Hamidon, 2011). Risanta et al. (2016) developed a vertical type *lemang* cooking device using electric energy and have an effective capacity of 1.42 kg h^{-1}. The cooking time for *lemang* requires at least 100 minutes to produce the best *lemang* organoleptic quality (Ferry et al., 2018). However, the previous equipment designs still have a lack and do not meet the needs of *lemang* producers, especially in Indonesia. In this paper, a new design of *lemang* cooking device was proposed by considering important parameter based on the requirement of the *lemang* producer in *Tebing Tinggi* City, Indonesia. The *lemang* is required to use bamboo due to the typical characteristic of cooking *lemang*, and is still using open fire cooking method due to the availability of biomass fuel such as coconut shells, corn cob and firewood. In addition, to eliminate the risk of hand burning and to reduce the overcook bottom part of *lemang*, it was proposed the continuous rotating system using driving motor and was combined with a tilt angle adjuster mechanism for developing the *lemang* cooking device.

(a) cooking on the table steel

(b) cooking on the concrete bricks

(c) cooking on the ground

Figure 1 An existing methods for cooking *lemang* in Indonesia

2 Materials and methods

2.1 Materials

The materials used for constructing the cooking device were selected based on material properties, availability, machinability, and economic considerations. Material properties were considered based on the strength of the materials, toughness, stiffness, and heat resistance. The material used in the performance tests was *lemang* that was prepared based on a common procedure for processing *lemang*. The cooking process was using coconut shells as biomass fuel due to availability and high calorific value which is 17.4 MJ kg^{-1} (Amoako and Mensah-Amoah, 2019). Coconut shell is a biomass waste and has not been much utilized so that it is quite appropriate when used for the cooking process of *lemang*. Coconut shell has the potential sources of carbon which can be utilized as alternative energy sources such as briquette (Yuliah et al., 2017).

The bamboo (*Bambusa vulgaris*) used as media for cooking *lemang* has a diameter of 50-70 mm, length of 500-600 mm, and wall thickness of 8-10 mm. The basic density of the bamboo, according to Wahab et al. (2009) is around 472.6 - 591.8 kg m^{-3}. The physical characteristic of bamboo is needed for designing a *lemang* cooking device.

2.2 Cooking device design and principle

The general purpose of the cooking device is distributing heat to all *lemang* processed uniformly, without having to rotate the *lemang* bamboo manually. To obtain the appropriate cooking device design with the needs, there are some features considerations that should be on the cooking device. The design criteria consist of:

Lemang cooking must use bamboo stalk for placing glutinous rice material (can not be changed with other material)

Lemang bamboo container must be able to rotate the bamboo which have dimension 50 - 70 mm of outer diameter and 500-600 mm of length

Lemang bamboo is rotated continuously due to the cooking process with low rotational speed (it is around 15 rpm)

Parts of the cooking device are made from sturdy and heat-resistance materials

The Cooking method uses direct fuel-burning system using available local biomass fuel (coconut shells, corn cob, firewood)

The expected *lemang* capacity is 36 *lemang* per batch

The Cooking device is designed to have a tilt adjuster mechanism

The Cooking device is movable (easy to move)

Based on criteria design, functional analysis was conducted to describe the main function and sub-function, then derived it to the necessary component that were chosen for constructing the device (Sagita, 2019). The functional analysis result of the cooking device is shown in Table 1.

Lemang cooking device has several important parts. Parts of the device consist of frame, bamboo rotating container, burning container, chain and sprocket transmission, tilt angle adjuster, and electric motor as a power source. *Lemang* bamboo container was designed to be able to accommodate bamboo with a diameter between 50 to 70 mm so that the container design was considered to have a conical form with a diameter of 50 - 80 mm. The scheme of the bamboo rotating system and bamboo container design are shown in Figure 2.

Table 1 Functional analysis of *lemang* cooking device

Main Function	Sub Function	Component
Cooking and rotating the *lemang* bamboo continuously using a direct fuel-burning system with a capacity of 36 *lemang* per batch	Propping up the parts of the cooking device	Angle iron bar with material mild/low carbon steel (ASTM A36)
	Placing bamboo stalk with a diameter of 50-70 mm	The bamboo containers have a conical form (50 mm to 80 mm)
	Rotating *lemang* bamboo continuously	An electric motor
	Connecting the rotation of 36 *lemang* bamboo	Chain and sprocket transmission
	Reducing the motor speed	A gear reducer
	Adjusting the bamboo tilt angle	Hinge mechanism using radial ball bearing
	Placing the fuel	Rack made of mild/low carbon steel

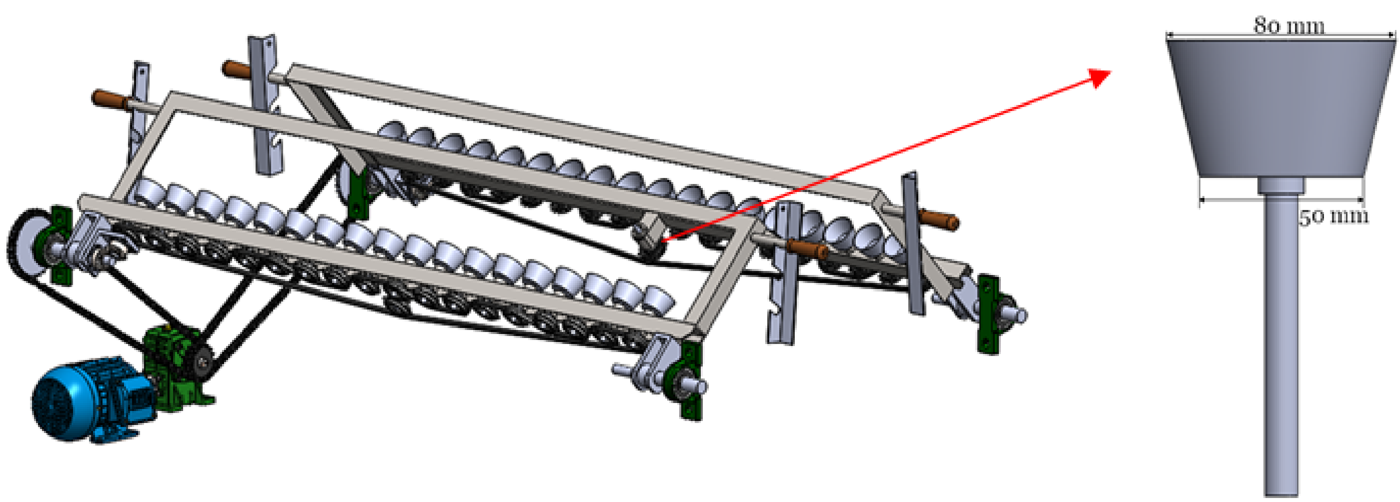


Figure 2 The schematic transmission system of the bamboo cooking device and bamboo container design

All parts of the *lemang* bamboo container were constructed and placed on the adjustable supporting frame. There were two sets of supporting frames (left-side and right-side) that can carry on 18 bamboos for each side. It is crucial to make sure that the bamboo supporting frame is strong enough and no deflection occurs while all bamboo with the rice is placing on it. The weight of bamboo stalk used is 0.4 kg per stalk (based on the maximum dimension and maximum density) and the weight of both rice and coconut milk is around 0.22 kg per stalk. The total weight of the 18 bamboo stalk with ingredients was 11.16 kg. Besides, other loads to be involved were the weight of the bar, bamboo container, chain, sprocket, and bearing which was assumed about 15 kg. Load estimation may occur to the supporting frame was 26.16 kg or 260 N. Finite element modeling (FEM) and analysis (FEA) were used for load simulation. FEM and FEA are among the most popular mechanical engineering applications offered by existing CAD / CAM systems. In finite element analysis, the body or structure is divided into a number of nodes and elements, known as discretization (Singh et al., 2019). In this case, load static simulation software (i.e., *Solidworks*) was used for observing stress, strain, and displacement that occurred on the bamboo supporting frame. It was conducted after the proposed design was finished by modeling in the CAD tool. The simulation follows the procedure exemplified by Chang (2015). The simulation was conducted using standard mesh configuration in *Solidworks*. The frame material used in the simulation was ASTM A36 mild/low carbon steel. The simulation result was shown in Figure 3. The maximum stress, strain, and displacement that occurred in the supporting frame were 2.84×10^{7} N m^{-2}, 7.85×10^{-5}, and 1.5 mm respectively. The stress value is far below the yield strength value (2.5 ×

10^8 N m^{-2}), strain and displacement also reveal the very low value. Based on the simulation, the supporting frame design has been qualified to be constructed using angle iron 40 mm×40 mm×3 mm with material ASTM A36 carbon steel.

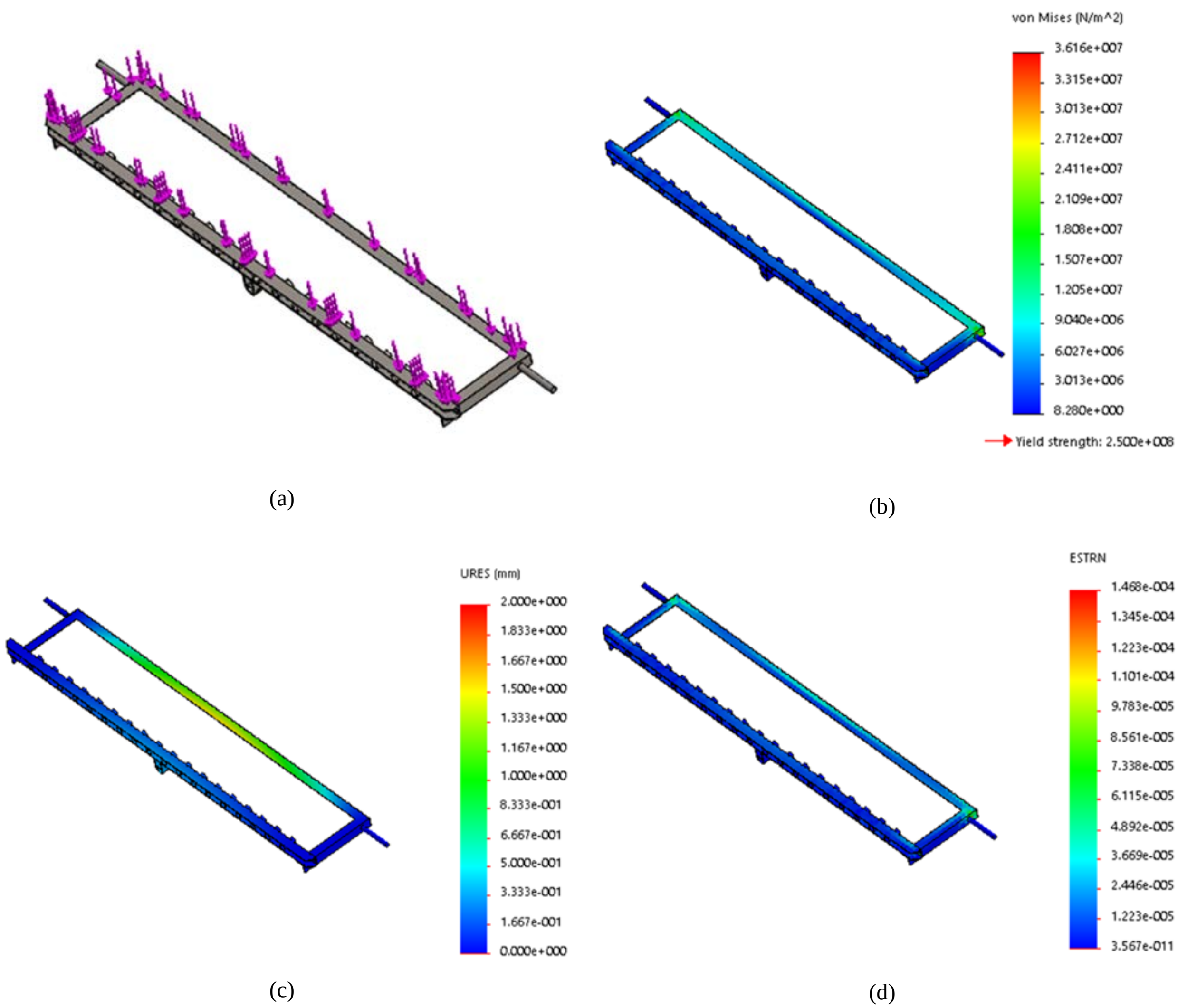


Figure 3 Load static simulation results of bamboo supporting frame: a) initial condition with load direction; b) stress analysis; c) displacement analysis; d) strain analysis

The continuous *lemang* rotating system consists of bamboo containers that were properly arranged and connecting to the chain and sprocket transmission system. The total capacity of the cooking device was designed 36 *lemang*/batch. The electric motor used has a specification of 0.5 hp, 1440 rpm, 1 phase, and 50 Hz frequency. The overall design of the cooking device integrated with a continuous rotating system is shown in Figure 4.

Lemang bamboo container was designed to rotate continuously and has low-speed rotation which is 15 rpm. Gear reducer (ratio 1: 60) and chain transmission (ratio 2:3) were used due to the requirement of the low-speed rotation. Bevel gear was used to change the direction of axis rotation. The mechanism for adjusting the tilt angle of *lemang* bamboo was added using a hinge mechanism and handle. There were three positions that can be chosen while the cooking process (i.e 15˚, 30˚, 45˚). The materials used for constructing the cooking device are listed in Table 2.

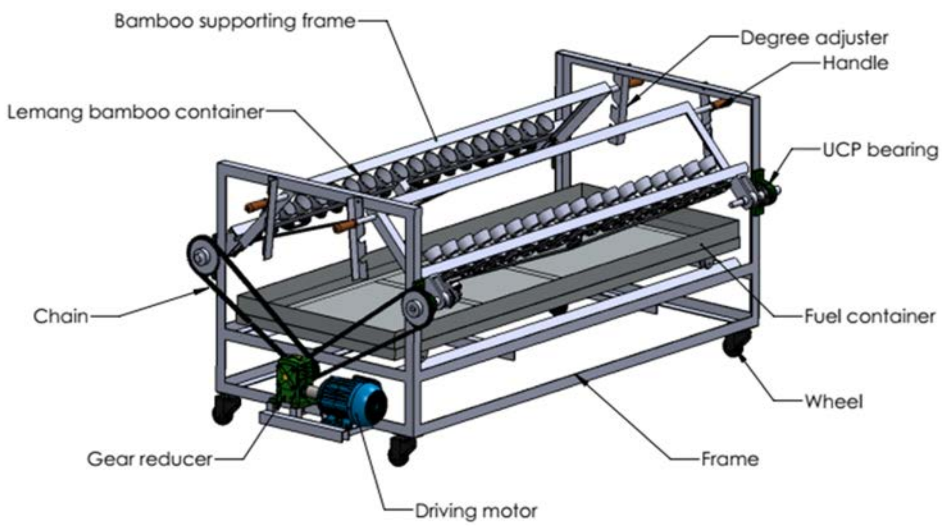


Figure 4 Design of *lemang* cooking device integrated with continuous rotating system

Table 2 Materials for constructing the cooking device

Number	Part Name	Spesification
1	Frame	Angle iron ASTM A36; 40 × 40 mm
2	Wheel	Trolly wheel, 2 inches
3	Fuel container	ASTM A36 / mild steel; 1.5 mm
4	UCP bearing	UCP 209; 30 mm shaft diameter
5	Handle	Wood material
6	Angle adjuster	Angle iron ASTM A36; 30 × 30 mm
7	Bamboo supporting frame	Angle iron ASTM A36; 40 × 40 mm
8	*Lemang* bamboo container	Mild steel; conical (diameter 50 to 70 mm)
9	Chain	Bicycle chain
10	Bevel gear	Module 2.5; number of teeth 19
11	Shaft of bamboo container	Iron shaft, 12 mm
12	Bearing shaft bamboo container	Type 6201zz; 12 mm inside diameter
13	Sprocket of bamboo container	18 teeth
14	Driving motor	0.5 horse power; single phase
15	Gear reducer	1:60

2.3 Performance evaluation

2.3.1 *Lemang* glutinous rice preparation

The glutinous rice was purchased from the local market in Subang, West Java, Indonesia, and had a moisture content of 14%. The processes of *lemang* preparation consisted of washing, soaking, rinsing, draining, mixing with salt and coconut milk then inputting to bamboo stalk with banana leaves coat inside. The diagram of the *lemang* rice preparation is shown in Figure 5.

2.3.2 Evaluating heat distribution in the heating area

The evaluation was conducted for observing heat distribution generated in the heating area during cooking. The temperature distribution was measured and recorded by using type K thermocouples with data logger *Daqpro* 5300. Thermocouples *were* set in the upper and lower position of the heating area and were set parallel with the *lemang* bamboo position as shown in Figure 6. There were four positions of thermocouples that were set in the heating area. The data logger recorded the temperature with an interval of 10 seconds.

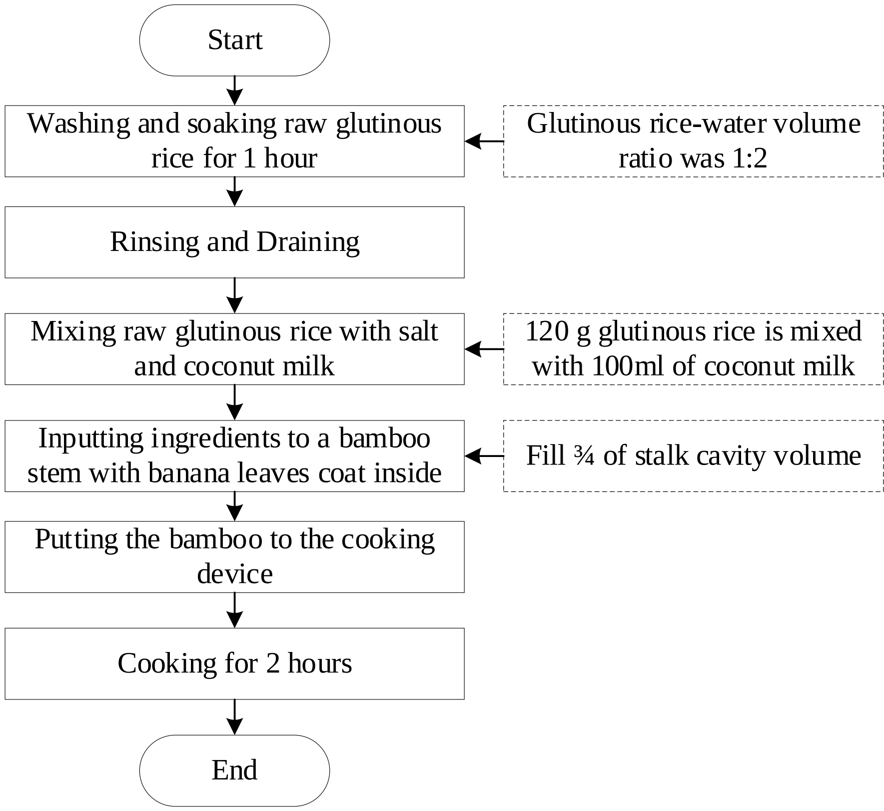


Figure 5 Diagram of *lemang* glutinous rice preparation for performance tests

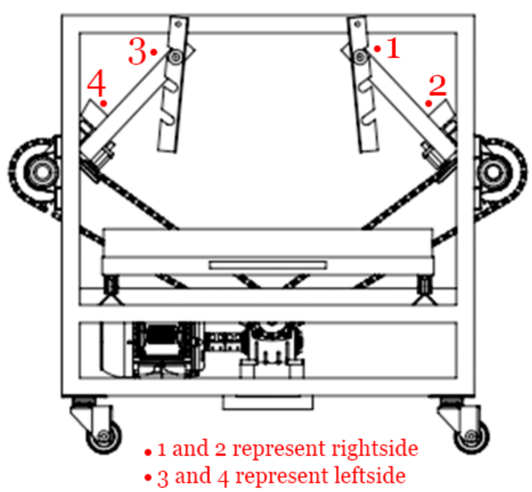


Figure 6. Thermocouples position in the heating area

2.3.3 Evaluation of bamboo surface temperature during cooking

The surface temperatures of bamboo were also measured by using *Fluke* infrared thermometer every 10 minutes. The temperatures were measured while the bamboo keeps rotating in the heating area. This evaluation was conducted to investigate the temperature distribution especially in the upper and lower position of bamboo. The test was carried out for 2 hours until the *lemang* rice was cooked. The coconut shells were added simultaneously to the burning container in order to keep the stability of heat. The measurement position of bamboo surface consisted of two positions for every bamboo as shown in Figure 7.

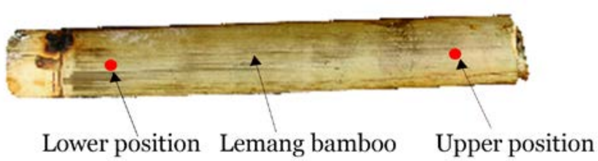


Figure 7 Measurement position of bamboo surface temperature during the cooking process using *Fluke* infrared thermometer

2.3.4 Calculation of specific energy consumption

Besides observing the heat distribution during the cooking process, other parameters evaluated were electric current, power, and specific energy consumption. The meaning of specific energy consumption (SEC) is to estimate the amount of energy used for producing a unit of product. SEC is commonly used due to its convenience, e.g., the amount of energy can be directly reported per number of products. Generally, SEC is calculated by dividing the amount of energy used with the amount of products (Lawrence et al., 2019). Specific energy consumption was determined based on the energy used for rotating the motor and the energy used for cooking the *lemang* per unit *lemang* processed. The energy consumption for driving motor is calculated using Equation 1 and the fuel energy consumption for cooking is calculated using Equation 2. Then the specific energy consumption is calculated using Equation 3.

$$E_1 = V \times I \times t \tag{1}$$

$$E_2 = m_{cs} \times C_p \tag{2}$$

$$SEC = \frac{E_1 + E_2}{n_l} \tag{3}$$

Where, E_1 is driving motor consumption energy (J), V is voltage (V), I is average electric current (A), t is cooking time (s), E_2 is fuel energy consumption (J), m_{cs} is mass of fuel (kg), C_p is the specific heat of fuel (J kg^{-1}), SEC is specific energy consumption (J kg^{-1}), n_l is amount of *lemang* processed (kg).

2.3.5 Statistical analysis

Statistical analysis was used to compare the bamboo surface temperature in several bamboo positions. Analysis of variance test (ANOVA) with a significance level of 95% was used for analysis, and SPSS version 21 was used as a tool for analysis.

3 Result and discussion

3.1 Prototype of *lemang* rice cooking device

A prototype of *lemang* glutinous rice cooking device integrated with a continuous rotating system has been successfully manufactured based on design criteria. This device has been able to rotate bamboo stalk continuously with a speed range of 15-16 rpm, and have a capacity of 36 bamboo stalk per batch. The construction of the prototype consists of the main frame, fuel container, tilt angle adjuster, bamboo rotating system, chain-sprocket transmission, and driving motor. The prototype is visually described in Figure 8. The overall dimension is 2140 × 920 × 980 mm.

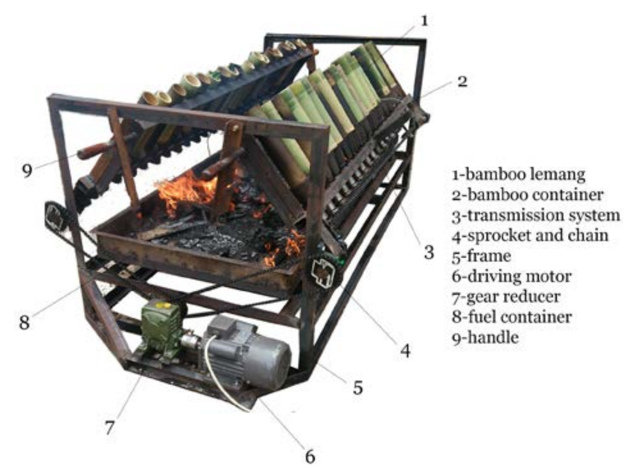


Figure 8 The prototype of *lemang* rice cooking machine integrated with a continuous rotating system

The continuous bamboo rotating system was developed to reduce the risk of work accidents such as hand burning. The tilt angle of the supporting frame for rotating the bamboo *lemang* container can be changed so that the upper position of bamboo can be evenly cooked. The step for cooking *lemang* in the device was divided into three stages. At the beginning of cooking (the first 40 minutes), the 45^o of tilt angle was used to avoid spilling of coconut milk, in the next 40 minutes, the tilt was changed to 30^o and in the last 40 minutes, it was changed to 15^o so that the upper position of the bamboos could receive more heat. There was a combustion rack that serves to produce heat from the burning process of fuel and was equipped with four wheels to facilitate the unloading of remaining matter from the process.

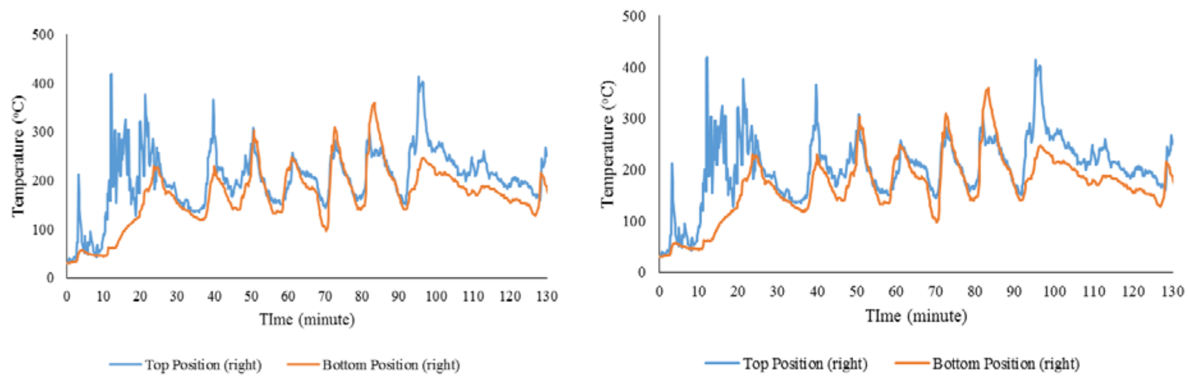
3.2 Heat distribution in the heating area

The first performance parameter of the *lemang* cooking device is the temperature distribution in the heating area (above the combustion rack). The temperature profile during the cooking process is presented in Figure 9. In this case, the level of heat generated from burning using coconut shells was quite high, ranging between 100^{o}C - 400^{o}C. The heat requirement for cooking rice, in general, is 100^{o}C (the boiling point of water). The temperature in the heating area was sufficient to be able to penetrate into the center of the bamboo considering that bamboo is a poor conductor in delivering heat so that the high-temperature decreases while it reaches the rice. Kiran et al. (2012) reported that bamboo material has a thermal conductivity value range from 0.12 to 0.38 W m^{-1} K^{-1} depend on its density, and this is what makes *lemang* cooking take a long time (about 2 hours). The value is almost the same with the thermal conductivity of wood which is 0.1 - 0.2 W m^{-1} K^{-1} and very different with carbon steel material which is 45 W m^{-1} K^{-1} (Franssen and Real, 2016).

The temperature above the combustion rack during the test was fluctuating depend on the fire generated and fuel availability in the rack. Coconut shells fuel were supplied simultaneously when the fire went out due to the decreasing of fuel. Thus, as shown in Figure 9, there was a gradual increase and decrease in temperature during the cooking process. It was also shown the change in temperature at the top and bottom positions for both the left-side and right-side. It appeared that at the beginning of the process which was 0-10 minutes, the temperature was still low due to the starting stage of the fuel combustion. After about 10 minutes, the *lemang* bamboo was placed on the cooking device. At the same time, the fire started to burn the fuel in the center of the combustion rack (ignition point) and then gradually spread around it. It made the temperature in the middle of the rack higher so that the measured temperature at points 1 and 3 (top position) higher than points 2 and 4 (bottom position). However, after the fire was spread, the temperature at the bottom position becomes the same as the top position and even some time higher due to its position that closer to the heat source. Overall, the temperature distributions have shown the value that did not differ between the top and bottom positions because the curve paths point much coincide. It was very difficult to make a fire stable using a direct combustion system. However, this was an effort solely to maintain the combustion method due to the use of the coconut shell that was a quite widely available source of fuel and also unused waste.

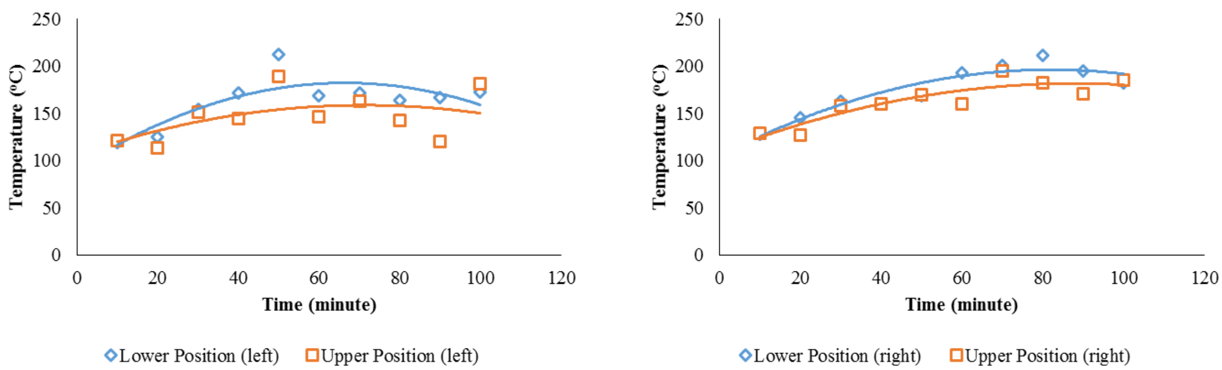
3.3 Bamboo surface temperature

Figure 10 shows the change in bamboo surface temperature during the cooking process. Based on Figure 10, it was revealed that the temperature trend of the lower bamboo position was higher than the upper position during the cooking process. This occurred due to the lower bamboo position which was closer to the heat source received more heat as also reported by Hussain and Hamidon (2011). The average temperatures at the upper and lower positions of the bamboo surface were 163.81^{o}C and 175.10^{o}C for the right-side and 147.52^{o}C and 162.69^{o}C for the left-side. To find out the significance, the ANOVA test was performed. Statistical analysis using the ANOVA test showed that there was no significant temperature difference between all positions of the bamboo surface (Table 3). This was occurred due to the use of the rotating system and proper tilt angle which is 45^o. The average temperature difference (ΔT) occurred was only about 11.29^{o}C and 15.17^{o}C for both right-side and left-side, but the deviation values were higher than the average temperature difference so that there was no significant difference in all positions. Wide variance value was caused by fluctuations of the fire during the combustion process, but the temperature changes occurred proportionally at all points in the combustion area so that the bamboo surface temperature also changed proportionally.



(a) left-side (b) rigth-side

Figure 9 Change of temperature in the heating area



(a) left-side of the device (b)

Figure 10 Bamboo surface temperature in the upper and lower bamboo stalk position during the cooking process: a); b) right-side of the device

The use of the open fire combustion method on this device could produce sufficiently proper heat and quite uniform due to it was supported by a continuous rotation system so that it could result in *lemang* cooked more evenly. Furthermore, the cooking process also runs more safely as the operators did not need to turn the bamboo during the cooking process.

Table 3 Comparison of bamboo surface temperature on the upper and lower position from both left-side and right-side

Factor	Temperature (°C)	SD (°C)
Upper position (leftside)	147.52	25.19
Lower position (leftside)	162.69	26.21
Upper position (rightside)	163.81	22.24
Lower position (rightside)	175.10	26.25
p-value	0.125*	-

Note: *SD*: Standard deviation;

*p-value > 0.05 indicated that there is no significant different

During the cooking process, there was a phenomenon of color change on the bamboo which can be seen visually. The increase in time results in a change in the color of the bamboo from dark-green to brownish-green, which means that the moisture content of the bamboo decreases. The fully-cooked indication of the *lemang* can be observed from the steam that no longer comes out through the top hole of the bamboo, there are no bubbles, and the rice expands until it is visible at the top of the bamboo. When this phenomenon occurred, the *lemang* cooking process was complete and the fire can be extinguished.

3.4 Specific energy consumption

Specific energy consumption for cooking *lemang* glutinous rice using the device was determined based on driving motor energy consumption dan fuel energy consumption. The result of the calculation is shown in Table 4. Energy consumption for rotating the motor was 6.49 MJ (2 hours test operation), besides, average fuel energy consumption was 623 MJ. The highest proportion of energy used was for cooking, reaching 98.9% of the total energy used. This was occurred indeed due to its main function which was for cooking *lemang*. Besides, the energy consumption for the driving motor was very slightly at 1.1% since the purpose was only to support the process so the *lemang* was maintained from overcooked on one side. The specific energy consumption for cooking single bamboo *lemang* using this device was 17.49 MJ per stalk or in another unit was 145.72 MJ kg^{-1} dry glutinous rice (the amount of glutinous rice is 4.32 kg dry glutinous rice per batch). The result was higher when compared to rice cooking in general. It was reported that the energy required to cook rice using a microwave was 3.2 - 4.8 MJ kg^{-1} of rice within a time of 15-22 minutes (Lakshmi et al., 2007).

The high energy requirement for cooking *lemang* was due to the cooking that was using an open fire, and heat came from fuel direct combustion. Furthermore, in the overall process, the heat received by glutinous rice transmitted by conduction through bamboo. Bamboo was not a good conductor, so much heat was lost only for heating the bamboo which was quite thick, and it was around 8.9 mm. Even when the bamboo surface temperature reaches 200^{o}C, the heat received by rice was probably still around 100^{o}C which was the boiling point of water as the experiments for cooking rice conducted by Kanjanapongkul (2017), Jittanit et al. (2017) and Gavahian et al. (2019). Besides, 2 hours of the cooking process affected the required energy becomes greater too. However, this is where the challenge is that in further research, it is necessary to improve energy efficiency of this device. One of the prospects is using dual fuels (e.g. open-fire and gas burner). Thus, the use of coconut shells can still be used considering the coconut shell is a biomass waste that has not been much utilized.

Table 4 Calculation of Specific energy consumption

Parameter	Value	Unit
Voltage (V)	220	V
Electric current (I)	4.1	A
Mass of fuel (m_{cs})	35.82	kg
Cooking time (t)	7200	s
Specific heat of fuel* (c_p)	17.40	MJ kg^{-1}
Driving motor consumption energy (E_1)	6.49	MJ
Fuel energy consumption (E_2)	623.27	MJ
Amount of *lemang* processed (n_l)	36 (4.32)	Product (kg)
Spesific energy consumption (*SEC*)	17.49	MJ per *lemang* product
Spesific energy consumption (*SEC*)	145.72	MJ kg^{-1} dry rice

Note: *source from Amoako and Mensah-Amoah (2019)

4 Conclusion

A prototype of *lemang* glutinous rice cooking device integrated with a continuous rotating system has been successfully designed and tested. From the study conducted, it was found that the new design of *lemang* cooking device was capable of cooking *lemang* with no significant temperature difference between all positions of the bamboo surface ($p > 0.05$) during the cooking process (fairly uniform) as the impact of using a continuous rotating system. The device still using bamboo due to the typical characteristic of *lemang* cooking and still using open fire cooking methods due to the availability of biomass fuel. By using a continuous rotating system, the risk of hand burning and the overcook bottom-part of *lemang* can be reduced. This equipment can be applied directly to *lemang* producers and can even be customized specifically related to its capacity because each *lemang* producer has a different production capacity. The advantage of using the continuous rotation system has been proven to be user-friendly with the heating results of the *lemang* which is quite evenly compared to manual cooking, does not cause excessive fatigue, and avoids the risk of hands burning. Also, because the operator does not need to turn the bamboo during the cooking process, the operator can spend his time doing other tasks such as making and filling other dough for the next batch production. The use of this equipment may increase operational costs because it uses electricity of 0.375 kW, but this addition is very small, where the price of electricity per kWh in Indonesia is 1500 IDR (0.1 USD) per kWh, so the electricity consumption is only 0.75 kWh per batch (2 hours) or around 1125 IDR (0.075 USD) per batch, make it very feasible to be applied.

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