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# Improving homogeneous chamber temperature of biomass dryer by automatic air controlling system

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**ABSTRACT**

Biomass dryer (BD) was a useful device to improve the time efficiency of drying activities in traditional systems. The fuel source of biomass can be obtained from agricultural wastes, such as corn cobs and coconut shells. The classic problem of BD is the inhomogeneous temperature inside the chambers, which leads to damage to the product if the air circulation is not controlled. This study utilizes an electronic controller to automatically manage airflow by a fan and open the window to obtain a homogenous temperature in each chamber. The window will be opened instantly if the temperature inside the chambers exceeding 46°C. This testing sample product is a cracker, locally called 'krupuk'. Cracker is made from tapioca flour and dried for several days after cutting processes. Our previous test successfully improves time efficiency in drying the post-harvest agricultural product. The proposed dryer consists of cabinet with 3 chambers, an open fire drum, a couple of automatic windows, and an electronic board as a controller. The resulting test shows a homogenous temperature average for the 3 chambers is 50°C.

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## 1. INTRODUCTION

Cracker, locally called 'krupuk', is a traditional complemented food which almost found in Javanese and Malay foods. Cracker is made from tapioca seasoning with spices, fish, or shrimps [1, 2]. The longest step in cracker making is drying which traditionally uses sunlight to draw water content in the cracker. It can take a whole day in clear weather or in the worst condition, it can take 3 – 5 days for drying cracker by sunlight, especially when the rainy season is coming [3].

The low-cost and environmentally friendly option to substitute the sunlight is a biomass dryer (BD). This dryer provides time-efficient and continuously work without depend on the weather conditions. The common form of BD consists of a cabinet and fire drum [4-10]. In hybrid form, BD can be facilitated by a transparent roof incorporating sunlight to boost the drying time [11-16]. But, uncontrolled airflow of BD is a remaining problem to solve. The airflow inside the cabinet must be distributed for obtaining homogeneous temperature, especially for multi chambers cabinet. The inhomogeneous temperature inside the chambers will lead a poor product quality [17]. The heat from the dryer will reduce the moisture content in the product [18, 19].

Fortunately, an electronic controller can be utilized for the airflow by a fan and opening window management. This study modifies BD which supported by an electronics board and automated window to obtain a homogenous temperature in each chamber of BD. We use corn cobs and coconut shell as the biomass and shrimp cracker as the tested product. Corn cobs coconut shells have a high carbon content and can maintain in the coals stage for up to 7 hours [4]. Shrimp cracker is chosen for product testing because it can easily be found in the market. A study shows the shrimp cracker has nutritional contents, such as protein, and minerals [1, 2].

## 2. MATERIALS AND METHOD

### 2.1. Tools and Materials

Table 1. Tools and materials.

| Tools/Materials | Use for |
|---|---|
| LM 35 | Temperature sensing |
| Arduino | Microcontroller |
| Digital scales | Measuring mass of the crackers |
| Corn cob and coconut shell | Fuel source of biomass |
| Fire drum | A place for burning the biomass |
| Drying rack | A place for the crackers |
| Drying cabinet | Drying process room |

### 2.2. Proposed BD

The design of the proposed BD (see Table 1) consists of a cabinet with 3 chambers, an open fire drum, a couple of automated windows, and an electronic board as a controller as shown in Figure 1. The data obtained from drying using a tool will be compared with the data obtained from traditional drying. This cabinet type dryer consists of 3 chambers. This tool is designed in the form of a cupboard with a corncob waste biomass energy system that is environmentally friendly and more economical than other energies.

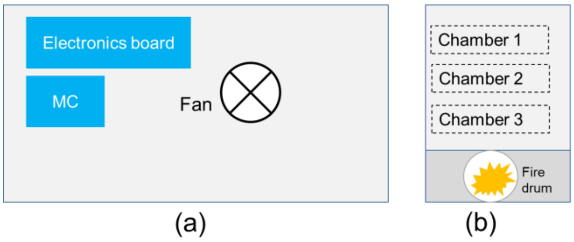


Figure 1. Schematic design of proposed BD: (a) top view and (b) side view.

### 2.3. Electronic Board

The electronic board consists of an Arduino, an LM35 sensor, and a buzzer. Arduino used as a microcontroller (MC) to control the temperature sensor and open the window. Moreover, four LM35 sensors are installed in each chamber and the outside for the temperature reader. LCD screen and buzzer is used as an indicator. Figure 2 shows the schematic design of the board.

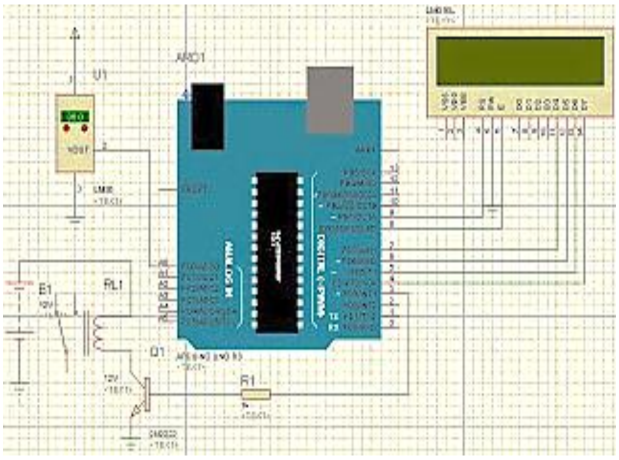


Figure 2. Schematic design of electronic board which consist of Arduino MC, LCD screen, temperature sensor (LM-35) and buzzer.

Arduino is programmed to give a signal when the temperature in the dryer is more than 46°C, the standard temperature for cracker drying [4]. When the LM35 sensor reads the temperature inside the dryer is more than 46°C, Arduino will give a signal to the buzzer to issue a sound as a signal that the temperature is more than 46°C so that the window will be opened to release the excess heat from the chamber. When the temperature inside the chamber has dropped below 46°C, the window door will be closed again. This condition can keep the product will receive stable heat along the drying stage and maintain its quality.

### 2.4. Testing and data collection

The crackers are put into the dryer and each rack is installed temperature sensor to measure the temperature on each chamber. The data collection process was carried out for 120 minutes with an interval of each 10 minutes. When drying has reached 10 minutes, the crackers that are dried in the dryer are removed. Then, the temperature on the side and bottom walls of the drying room, the left and right drums, and all chambers are calculated every 10 minutes using a thermometer and weighing the mass of the shrimp crackers using a digital scale.

## 3. RESULTS AND DISCUSSION

The final look of our proposed BD is shown in Figure 3. An aluminum plate has covered the cabinet and a fire drum is placed in the bottom. The electronic board is placed on the top to avoid heat. This BD is developed to provide a homogenous temperature of around 46°C. The proposed BD is a modified design from our previous design for the post-harvest dryer [4].

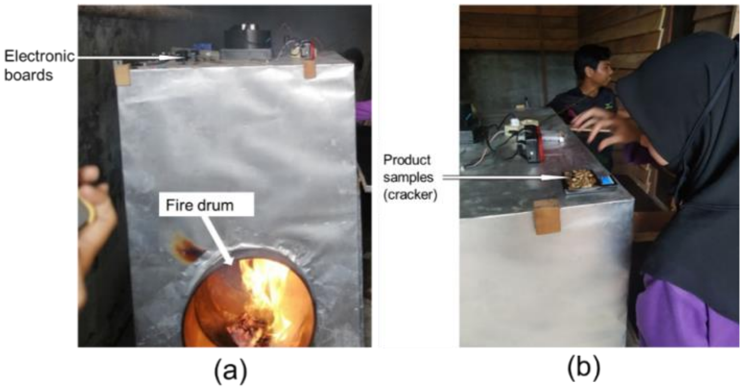


Figure 3. The realization of proposed BD: (a) the components of proposed BD and (b) testing product measurement.

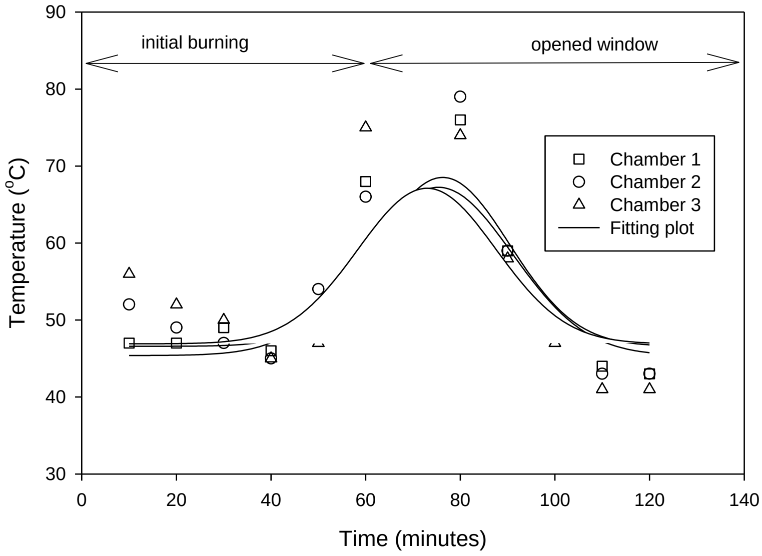


Figure 4. Temperature characteristics of each chamber for proposed BD.

Figure 4 shows that the working principle of the tool has worked well because it produces a temperature distribution that is almost homogeneous in the drying chamber with the resulting average temperature of 50°C. Thus the automation of drying technology can be immediately used in industries related to post-harvest drying [20-22].

When the biomass is burning, the cabinet temperature slowly down for 40 minutes and rapidly increases up to 75°C within 20 minutes. In this stage, the fuel is full flaming so the heat is highly transferred to the cabinet. Then, the automated window is discharged to open so that the temperature in each chamber drops significantly to around 50°C. The heat inside the cabinet is released to the outside. The chamber temperature re-climbing for ten minutes until dropping exponentially to around 46°C and homogenous temperature is reached. In this stage, the airflow is fully controlled and distributed after 110 minutes of initial biomass burning. At the same time, the burned biomass is keeping in coals condition.

Table 2. Curve characteristics of chamber temperature of proposed BD.

| Chamber | $T_0$ (°C) | $a$ (°C) | $b$ (s) | $t_0$ (s) | $R^2$ |
|---|---|---|---|---|---|
| 1 | 45.3836 | 21.8656 | 15.5904 | 75.4020 | 0.6308 |
| 2 | 46.5880 | 21.9449 | 14.0817 | 76.2880 | 0.5726 |
| 3 | 46.9051 | 20.2128 | 14.6350 | 72.9641 | 0.4308 |

The temperature characteristics of each chamber are likely to follow the Gaussian peak curve with four parameters.

$$T(t) = T_0 + a \exp\left(-\frac{1}{2}\left(\frac{t-t_0}{b}\right)^2\right) \tag{1}$$

The parameters are summarized in Table 2. The steady temperature $T_0$ is almost similar for each chamber as well as growth temperature $a$. The critical issue may come from the initial burning time $t_0$ to reach a steady condition were about 74 minutes roughly. This issue is commonly found in the BD. Coconut shell biomass is spent an hour or more to reach stable burning in coals condition [23]. Exploring new types of biomass fuel is suggested for future research to minimize the initial time burning. In addition, it is also expected to make automatic system updates with the Simulink-MATLAB model which can help improve accuracy in detecting room temperature [24, 25].

## 4. CONCLUSION

The chamber temperature of BD can be maintained by modifying the conventional BD. The proposed BD consists of a cabinet with 3 chambers, an open fire drum, a couple of automated windows, and an electronic board as a controller.  Air circulation in the BD is driven by a fan and an automated window. The exceeding heat will release through the automated window when the chamber temperature more than 46°C. A homogenous temperature of 50°C is achieved after 110 minutes. The temperature characteristics of each chamber are likely to follow the Gaussian peak curve with four parameters.

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