DESIGN AND TESTED A PILOT SCALE OF A GREENHOUSE HYBRID DRYER FOR FERMENTED CASSAVA SLICES

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ABSTRACT

A pilot scale of solar hybrid dryer for fermented cassava chips with wood-burning stoves as additional energy was designed and evaluated. The dimension of dryer was 9.2 m of length, 3.8 m of wide, and 3.54 of high, with capacity 768 kg. The dryer building is made from iron as main frame, Polycarbonate sheet 2 mm of thickness as wall and cement as roof. Tray is made from stainless steel wire mesh with wood and iron as a frame.The test results give 768 kg of fermented cassava chip could be dried in 9 hours, in which 94.3% of initial moisture content becomes 9.4% of final moisture content. The thermal efficiency of dryer is 53.82% with the wood consumption rate is 28.5 kg/h.

Keyword : mocaf, drying, hybrid, wood-burning stoves

INTRODUCTION

Drying is the process of removal of moisture from the solid product by apllying heat. The heat and mass transfer is occured simultaneously in drying process [1]. Sun drying is the earliest method for drying the agricultural product. However, this method has several disadvantage such as dust, insect, spoilage, depend on weather, etc. In addition, sun drying requires large land and drying time [2]. Furthermore, solar drying is more effective which can control the condition of of temperature and moisturere moving rate ensures perfect drying and desirable product quality [3]. The greenhouse is the most applied of solar dryer type for drying agricultural product [4]. Recently, the greenhouse dryer type is the most popular type and was developed for drying many food product such as cabbage and peas [5], agricultural product [6], grape [7], bitter gourd [8], papad [9], pepper and garlic [10], apple [11], chili, banana and coffee [12], coconuts [13], and seedles grape [14].

Cassava (*Manihot esculenta*) is one a tropical root crop that is processed into different food products. One kind of this product is modified cassava (mocaf) flour. Drying is the critical point in the process production of mocaf flour. In the production of mocaf, the fermented cassava chips have a moisture content of 60-98% (wet bases) and must be dried becomes 14%. Several researchers was conducted to decrease the moisture content of cassava chips or slices. The cassava slices succesfully dried in a mixed mode natural convection solar dryer [15]. Drying can reduce cyanide content in flour [16]. The photovoltaic solar dryer was produce export grade cassava dried [17]. However, for drying fermented cassava chips with greenhouse dryer is still less investigated.

Therefore, the main aim of this paper is develop the roof type greenhouse dryer for drying fermented cassava slices. The process design, testing, and performance of dryer will be presented.

DESIGN CONSIDERATION

The greenhouse dryer was built in smal medium enterprise (SME) mocaf flour in Wonogiri, Central Java, Indonesia. Materials for constructions dryer and trolley tray type dryer consisting of polycarbonate for the roof, galvanish pipe, steel plate, angle steel, and metal box, aluminum wire mesh, fan with 50 cm of diameter, and fireproof bricks. The sample fermented cassava chips from SME. The gasoline is used as fuel of diesel. The firewood is used as fule of burner. Equipments are fabricated in workshop such as welding machines, plate cutting tools, hand drill, grinder cutting, plate bending tools and others. Testing equipments are thermohygrometer, moisture tester, anemometer, pyranometer, digital scales, thermocouple, data recorder, rough scales, stop watch, measuring cups and others.

Determination of the dimension of tray and dryer

The drying capacity is 768 kg. Mocaf chip bulk density is 560 kg/m^3. Volume chip mocaf is (drying capacity) / (bulk density) = 1.37 m^3. Mocaf chip thickness is 0.015 m. Shelf area is (mocaf chip volume) / (thickness drying) = 91.33 m^2. Drying rack dimensions (H x L): 1 x 0.6 is 0.6 m^2. The number of racks required = (Area of rack) / (dimensional shelf) = 152 racks. The distance between the shelf is 0.3 m, and for the bottom shelf is 0.5 m from the floor of the dryer. The total height of tray is 2.2 m, consist of 1.4 m of high and 0.7 m of the distance to the roof top shelf dryers. The dimensioan of tray is 1 m of long side, consisting 0.5 m of the right side and 0.5 m of the left side. In the midle between trays is empty area 1 m to facilitate the mobility of the entrance. Finally the total dimensioan of dryer is (H x L x H) = 6000 x 3000 x 2200 mm.

Calculation of power

Xin is 95%. Xout is 9%. Massa of mocaf chip is 1000 kg. Drying time is 9 h. Yield = (100-Xin) / (100-Xout) = 0.99. Evaporated water weight (Mw) = mass-(yield x mass) = 10 kg of water. The rate of water evaporated = Mw / (drying time) = 0.0028 kg/s = 0.3 g/s. Drying temperature is 60 °C. Environmental temperature is 30 °C. Mocaf specific heat (Cp): 3.074 kJ/kg^{0}C. Mocaf latent heat (Hfg) is 950 kJ/kg. Power calculation for heating mocaf chip (P1) = (m_ (p) x Cp (T_d-T_a)) / t = 10 246, 67 W = 10.25 kW. Calculation of power to evaporate water mocaf chip (P2) = (M_w x H_fg) / t = 1.05 kW. Power required to dry the chips mocaf (P3) = P1 + P2 = 11.30 kW. The velocity of air flow between the chip mocaf: 1 m/s. Directional cross section of the air (L x T): 2 x 1.2 m = 2.4 m^2. Capacity blower = cross-sectional area x velocity air directional airflow = 2.4 m^3/s = 8640 m^3/h. Blower specification is axial fan of type. Size is 2.4 inch (600 mm). Capacity is 8704 CMH. Speed is 1400 rpm. Power is 600 W.

Calculation of Heat Exchanger

It is assumed that heat losses is 30% from the heat generated by the heat exchanger. Then drying energy requirements amounted to 15.70 kW / 70% in the amount of 22.43 kW. The amount of heat exchanger pipe area requirements are as follows: Q / efficiency = h x A x ΔT, where Q = energy requirement for drying (W), h = coefficient of thermal convection (W/m.K), A = cross-sectional area (m^2), ΔT = Difference room temperature and heat exchanger. Then A = 22430 / (100 x 130) = 1.725 m^2. Pipe heat exchangers used 2-inch pipe with a length of 1 m with such a broad cross-section of the pipe used is 0.1595 m2. Thus it takes as many as 11 pipeline pipe.

Calculation of Fuel

Assumed thermal efficiency furnace is 40% so that the heat that is needed is 22.43 kW / 40% in the amount of 56 075 kW. Furnace used is biomass wood-fired furnace with a calorific value of 14,400 kJ/kg. The rate of combustion of the fuel that is needed can be calculated with the following equation: L = Q/N = (56,075)/14400 = 0.00389 kg/s = 14:02 kg/h, where: ` L = The rate of fuel, Q = heat requirement (kW), N = heating value of wood (kJ/kg).

RESULTS AND DISCUSSION

Process Design

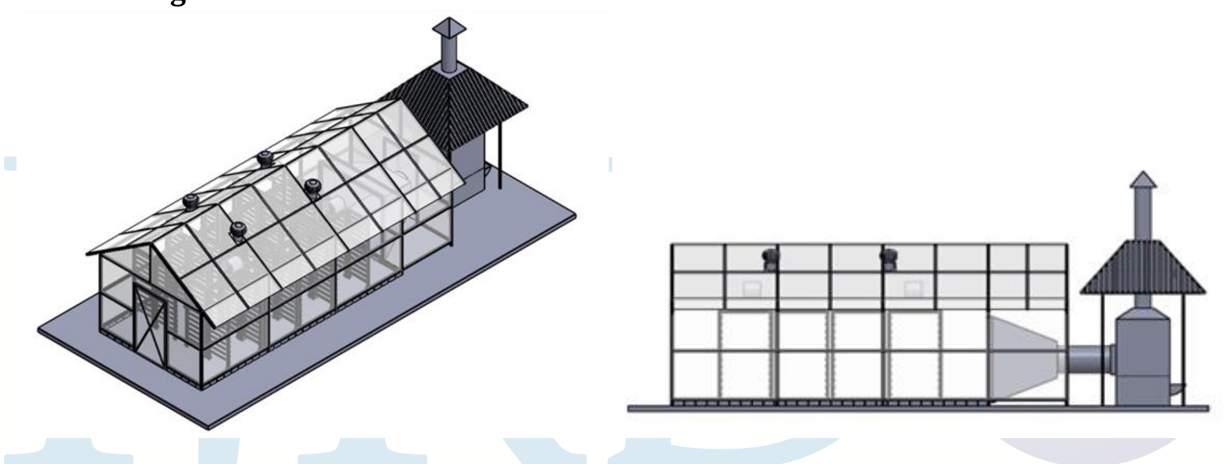

Fig. 1. The design of greenhouse hybrid tray dryer

Fig 1 shows the design of greenhouse hybrid tray dryer with the additional heat is biomass. With this model, the drying can be conducted with a thin stack, then the final moisture content chip mocaf more evenly. The walls and roof of the dryer is made with transparent polycarbonate plastic. The dimensional of dryer is 3 x 6 m. Dryer roofs made of polycarbonate plastic due to has a stronger structure and easy to set up. Then the dryer was modified as shown in Fig. 2.

Fig. 2. Greenhouse dryer before and after modification

Fig 3 shows the tray and trolly. Designed shelves stacked with distance between shelves 10 cm to simplify the income and expenditure mocaf chip and arranged vertically in a single 12 rack trolley. Order a rack made of angle iron 20 mm and wire mash for hot air circulation. Shelves made with a size of 1 x 0.6 m with a capacity of 4 kg/shelf, so that dryers are designed with as many as 192 rack shelf for 16 trolley. Trolley made of angle iron 3 x 3 x 3 mm and are made with a size of 1 x 60 x 1.7 m. At first trolley made elongated and difficult to move so that the trolley modification this time made one trolley each already no wheels to facilitate the transfer and play back trolley.

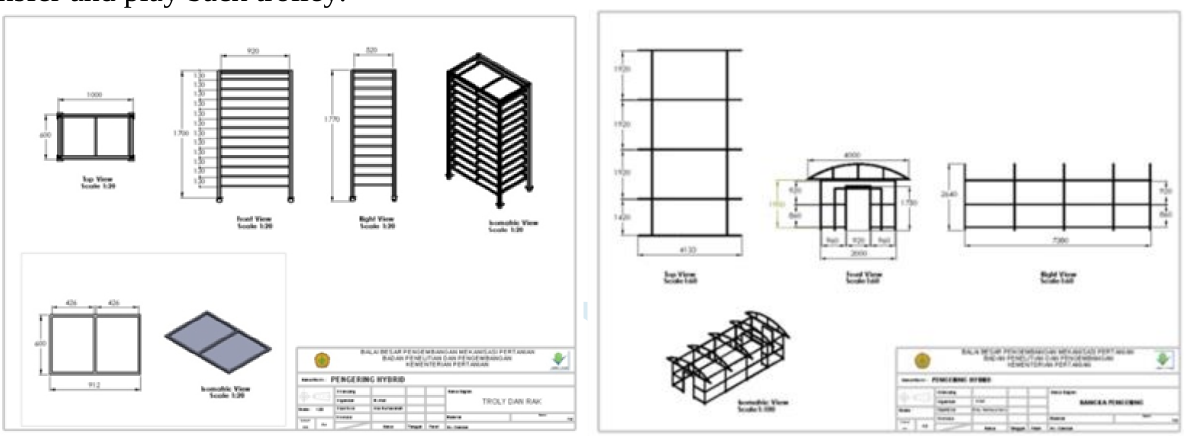

Fig. 3. The design of tray and trolley

Fig 4 shows the designed furnaces and heat exchanger. The furnace used to burn biomass, heat generated from the combustion will heat up further heat exchanger. By using heat exchanger, air entering the drying chamber is not mixed with the combustion fumes and dust combustion products that could eventually alter the taste of dried mocaf chip. Heat exchanger which is used in the form of 2-inch iron pipe with a length of 1 meter by 60 pieces equipped with a smoke exhaust stack pipe made of 2 mm thickness galvanish 6 inch diameter with a height of 3 m.

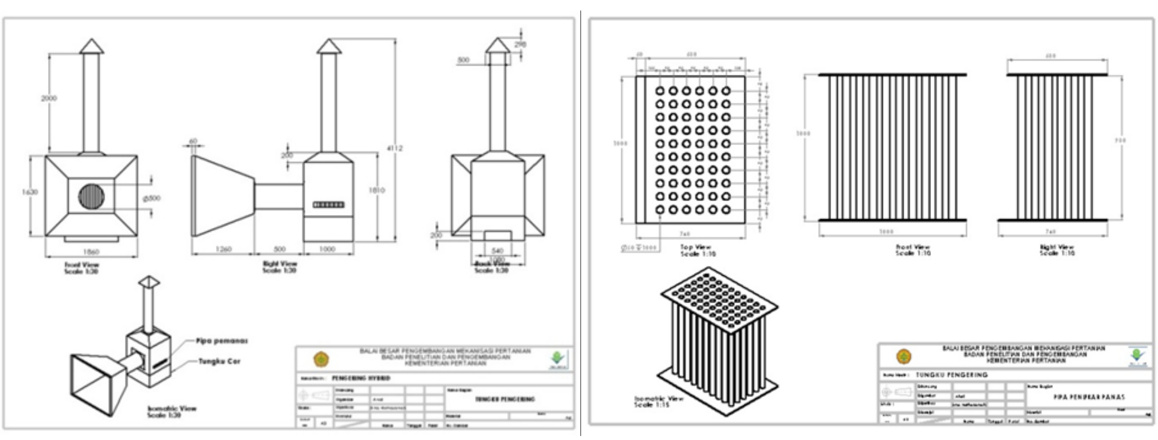

Fig. 4. The design of furnace

Blower is used to circulate the drying air. The hot air that has passed through the heat exchanger is blown into the house through the fabric and dryer directly out through the vortex that were placed at the top of the home dryer. Blowers are used are the type axial diameter of 24 inches (50 cm) with consideration of this type blower can blow the air with a turbulent flow so that the entire room can be exposed to the air dryer drying relatively more evenly.

Fig. 5. Heat exchanger and furnace

The dimension of turbin is 400 mm of diameter entry hole and mounted on the roof of the house dryer. Initially turbine 4 (four) pieces and then after modified it only takes 1 (one). This turbine serves to help the circulation of hot air that carries water vapor out of the home dryer. Hot air coming out of the blower will pass the stack of chips mocaf wet and bring a water vapor out through the turbines.

Performance Test

Performance testing conducted using the chip as much as 768 kg mocaf a wet fermented cassava chips with an average moisture content of 94.3% and dried to 9.4% moisture content for 9 h. The weather conditions at the time of drying overcast afternoon at 16.00 done so that the heat is used for drying only comes from burning biomass. Hot air for drying is generated from the furnace with wood fuel. The heat from the stove is channeled through drainage tube heat for inhaled and exhaled by the blower into the drying room. Tests carried out at a temperature of 70-80 °C plenum with the heating system used is indirect heating system. Blowers are used axial type with a horizontal position, amounted to one fruit, diameter 600 mm, the amount of fruit and a round blade 7 with speed of 2080 rpm. The blower mover is a diesel engine of 6.5 HP. Ambient air temperature on average when the test was 28.4 °C with an average humidity was 74.0%. The time needed to dry the chips mocaf of water content of 94.3% to 9.4% takes 9 h thereby drying rate average of 9.33 % /h. Observation of the chip mocaf before and after drying can be seen in Table 1.

Table 1. Results of performance test

Parameter	Results
Initial water content	94.3 % (db)
Final water content	9.4 % (db)
Drying time	9 hour
Air velocity	2 m/s
Air temperature inlet	70.67 ^{o}C
Temperature of the material	52 ^{o}C
Decline rate of of water content	9.33 %/hour
Consumption of wood fuel	28.5 kg/hour
Drying thermal efficiency	53,82 %

Fig 6. Fermented cassava chip after drying

The drying process can be carried out smoothly and without any smoke that enters the drying chamber because the chimney was modified to become a height of 3 m so that the smoke can all come out through the chimney. Other things were modified from the old dryer was burning furnace converted to the combustion section is made of fireproof stones and made permanent so that no heat is lost, the long drying machine furnace bottom is made of iron plate so rusty as shown in Fig. 6. The drying curve of cassava slices showed a reduction of moisture content with increased drying time in the solar dryer, and the variation of moisture ratio exponentially decreased with increased drying time.

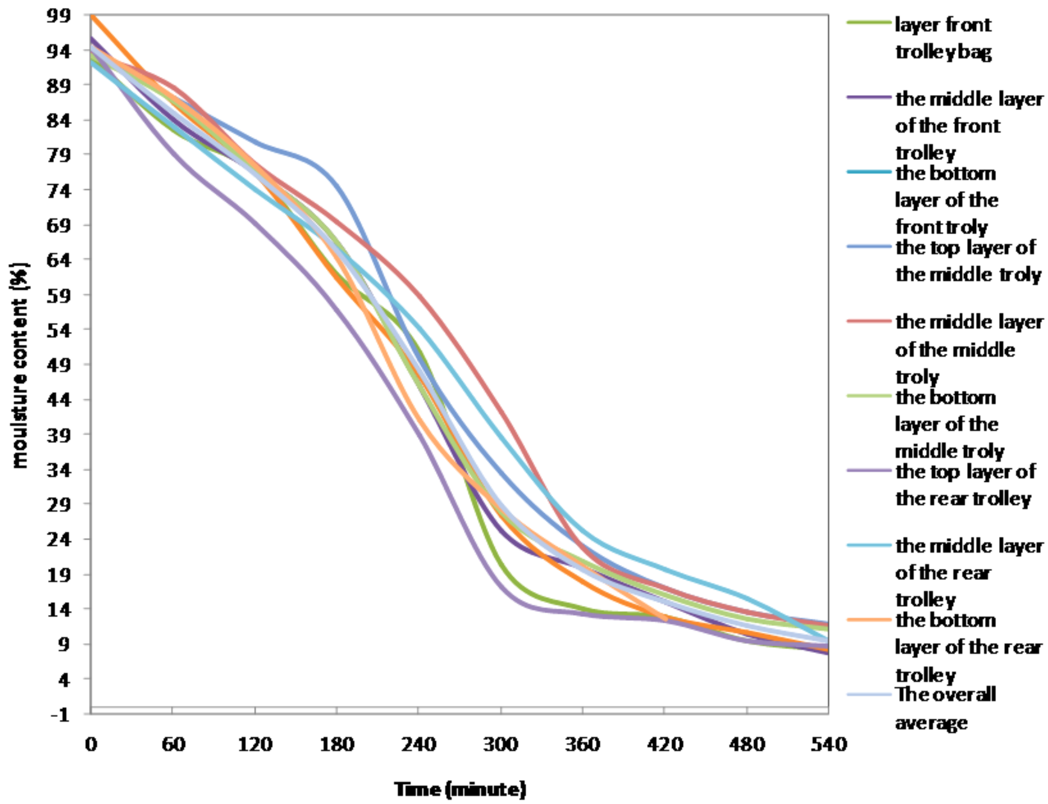

Fig.7 Drying curve of fermented cassava slices

CONCLUSION

Overall all aspects of the development of the dryer mocaf both technical and economical modification has been completed fully carried out and resulted in the installation and training of the dryer mocaf modifications in processing farmers' groups mocaf Girimarto-Wonogiri. Drying 768 kg or 0.768 tons of chips mokaf with initial moisture content of 94.30% to 9.40% final moisture content performed for 9 h with drying rate 9.33 %/h and heat drying efficiency 53.82%.

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