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Full Paper

GREEN DRYING CHAMBER BY USING VIBRATION COMPONENTS, HEAT EXCHANGER AND MICRO HYDRO IN BUTON ISLAND, INDONESIA

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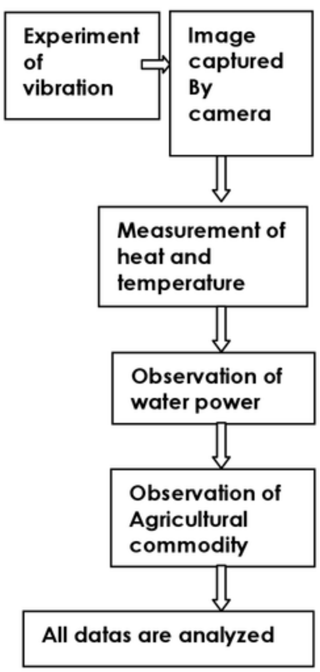
Graphical abstract



Abstract

The application of vibration components cause vibration on trays so hot air will hit the entire surface of the agricultural commodity on the drying trays. This condation results effective motion of agricultural commodity. Usually drying chamber for agricultural commodities was depend on electrical energy from government company. Green drying chamber for this research will not take electrical energy from government company because Buton Island has many rivers and water power in Buton river will be changed to electrical energy by using micro hydro power plant. The objective of this research is to perform analysis about effective motion, heat and air temperature, and water power for green drying chamber in Buton Island, Indonesia. This research uses observation, analysis and experimental methods and cashew nuts as sample of agricultural commodity in the drying chamber. In the year of 2005 Buton Island produced cashew nuts 6,856 ton, that's why the total length of the green drying chamber in this researh is 4.83 m and its drying chamber has a dimension of: length 4 m, width 3 m, height 2 m and it needs temperature 60 °C. Based on analysis results are found that the effective motion of the cashew nuts will occurred at the ratio 0.97 – 0.99. Required heat energy is 117.67 kJ/s and the average air temperature in the drying chamber can be achieved if the air temperature after flat plate heat exchanger is 78.25 ° C. Based on the observation and analysis results were found that Buton river had a Potential Head 47 m, Capacity 0.9 m^3/s, Design Capacity 0.35 m^3/s, Water Power 161.3 kW, Electrical Power Output 99.4 kW.

Keywords: Vibration; Heat; Water Power; Drying

1.0 INTRODUCTION

There are some drying chambers which have been used by famer groups in Buton Island, for example the drying chambers used coal fuel and heat absorber of solar energy that was placed out side of the drying chamber. However the fuels were not environtmently friendly whereas the drying chambers were not efficient and also having some problems, namely:

a. If the heat absorber was placed outside of the drying chamber then there had to be an addition of construction to place heat absorber.
b. On a certain time the agricultural commodity should be taken out of the drying chamber to be manually moved and this case will arise heat losses due to the drying doors opened oftenly.
c. The operation of the mean and infrastructure of drying chamber still uses electrical energy from the government owned electrical company.

The heat absorber could be placed in the drying chamber [2]. Carbon fiber was used as heat absorber where portion for solar energy was 33.3 % [4]. The agricultural commodity in the drying chamber could be moved by trays vibration and the angular speed near its natural frequency will result the effective motion of agricultural commodity [2]. Water power could be changed to electrical energy by using micro hydro power plant for electrical power output 50 kW – 500 kW [5]. To resolve the problems then a Green Drying Chamber (GDC) which is equipped with vibration components, heat axchanger, micro hydro and also the reuse of hot air from the drying chamber will be analyzed in this research. The objective of this research is to perform analysis about effective motion, heat and air temperature, and water power for green drying chamber in Buton Island, Indonesia.

2.0 THE OBSERVATION, ANALYSIS AND EXPERIMENTAL

The analysis and experiment of vibration, heat and air temperature were conducted from January 2011 until February 2012 in the Laboratory of Heat and Mass Transfer, Bogor Agricultural University. While the observation and analysis of water power and also agricultural commodities were conducted from March 2013 until April 2013 in Buton Island, Indonesia. The instruments and material that were used in this research include: Thermocouple, Tachometer, anemometer, Pyranometer, Ruler, Weighter, fuel and Stove, Heat Exchanger, Trays, Drying Chamber and the material tested was cashew nuts.

2.1 Vibration

Vibration components were placed under the drying trays and consist of electrical motor, spring, total mass, and unbalance mass which was connected to the motor shaft. To find data for effective motion in this study, total of mass and unbalance mass were measured using weighter, and its length using ruler. Electrical motor was operated and its rotation speed was measured using tachometer. These datas could be used for analysis of ratio and vibration amplitude. This is illustrated in Figure 1 and figure 2. The total of mass (M), Proportionality constant (k), Rotation speed (n), Unbalance mass (m) and its Length (e). Vibration Amplitude (X), Ratio (r), Angular speed (ω), and Natural frequency (ω_n) [7] are given by,

$$X = \frac{me\omega^2}{\sqrt{(k - M\omega^2)^2}} \quad (1)$$

$$\omega = \frac{2\pi n}{60} \quad (2)$$

$$\omega_n = \sqrt{\frac{k}{M}} \quad and \quad r = \frac{\omega}{\omega_n} \quad . \quad (3)$$

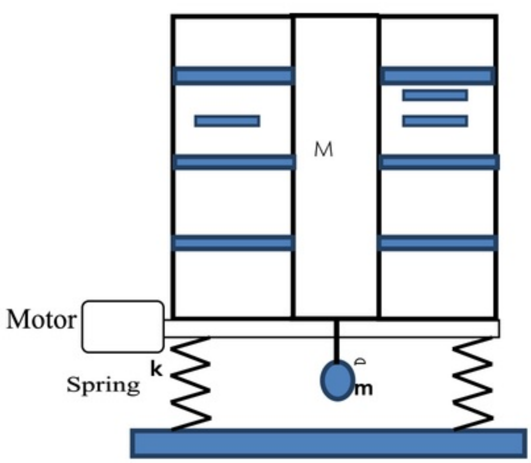


Figure 1 Vibration components

Figure 2 Cashew nuts and vibrated drying trays

2.2 Heat Transfer

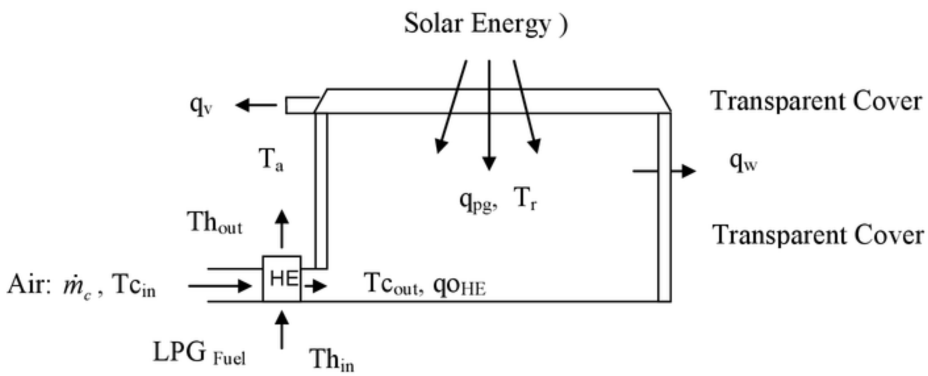


Figure 3 Fuel and solar energy for drying cashew nuts

This drying chamber applied fuel and solar energy to dry cashew nuts in the drying chamber, and the required air temperature in the drying chamber was 60 °C for 10 hours drying time [2]. The air velocity was measured using anemometer, the air temperature was measured using thermocouple and solar irradiation was measured using pyranometer. These datas were used for analysis of heat transfer (qo_{HE}) and temperature after heat exchanger. This is illustrated in Figure 3. The air temperature before and after heat exchanger are Tc_{in} and Tc_{out}, ambient temperature is T_a, difference of maximal temperature is $\Delta T_{max.}$, specific heat is cp, mass flow rate is $\dot{m}$, effectiveness is ε, heat capacity for air and gas of fuel are C_c and C_h. The heat transfer and air temperature are given by,

The heat transfer in heat exchanger [1],

$$qo_{HE} = \dot{m}_c \; cp_c \; (Tc_{out} - Tc_{in}) \qquad (4)$$

The air temperature after heat exchanger [3],

$$Tc_{out} = Tc_{in} + \frac{C_h}{C_c} \; (\varepsilon) \; (\Delta T_{max.}) \qquad (5)$$

2.3 Water Power

Water power in Buton river will be used to rotate a turbine so electrical energy will be obtained by using of a generator that has been connected to the turbine. The turbine and the generator are located in the power house. This is illustrated in Figure 4. Observation was done on several rivers and several agricultural commodities, and then data of potential head, capacity, condation of river and water fall, and the total of agricultural commdities were taken from government office in Buton Island. These datas were used for analysis dimension of green drying chamber and also for analysis of water power and electrical power output.

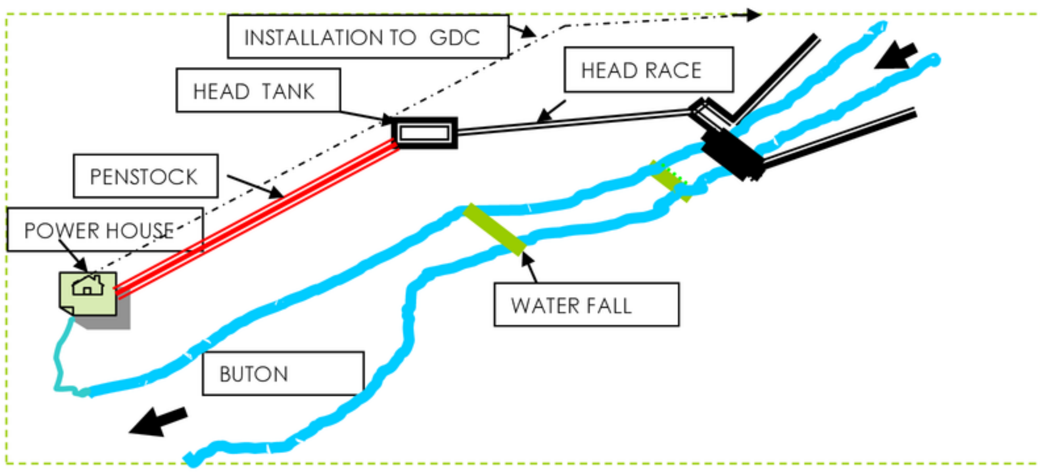


Figure 4 Water Power in Buton River

3.0 RESULTS AND DISCUSSION

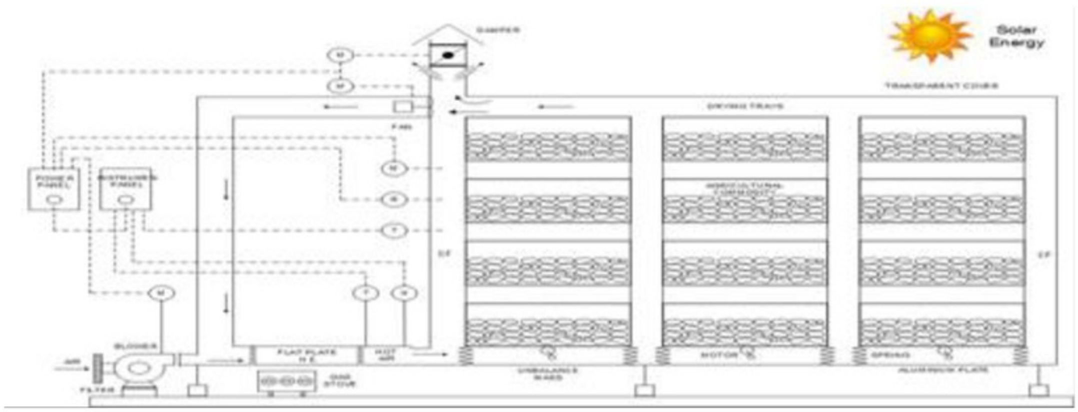


Figure 5 Green Drying Chamber by using Vibration Components, Heat Exchanger and Micro Hydro

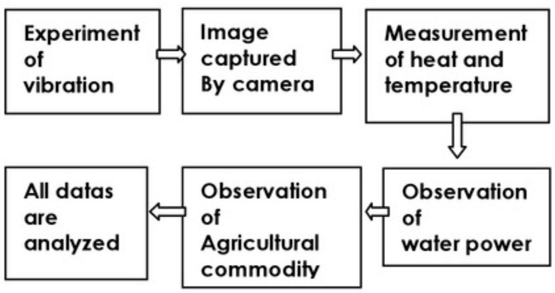


Figure 6 Block diagram of the process of the system

The application of vibration components cause vibration on trays so hot air will hit the entire surface of the cashew nuts on the drying trays. That's why, during drying process the doors of the green drying chamber are not necessarily to be opened. This condation results effective motion of cashew nuts as sample of agricultural commodity. According to datas from government office was found that in the year of 2005 Buton Island produced cashew nuts 6,856 ton, That's why the total length of the green drying chamber in this study is 4.83 m and its drying chamber has a dimension of: length 4 m, width 3 m, and height 2 m. Left side wall and right side wall and the floor are made in three layers and consist of aluminium plate with thickness of 0.001 m, glass wool with thickness of 0.1 m and aluminium plate with thickness of 0.001 m. Whereas the front wall, rear wall and the roof are made of transparent cover with thickness of 0.006 m. This is illustrated in Figure 5. A heat exchanger applied in this study is a flat plate heat exchanger having a dimension of: length 0.4 m, width 0.6 m, height 0.3 m, 12 air passages, effectiveness 43 % and this heat exchanger is made of aluminum plate material with thickness each plate is 0.001 m. The green drying chamber is equipped with LPG (Liquified Petroleum Gas) fuel and stove, carbon fiber, some rotation speed of electrical motor and temperature gauges, 1 blower of 0.75 kW, 1 exhaust fan of 0.75 kW and each drying tray has 1 electrical motor of 2.2 kW and 120 kg cashew nuts. This Green drying chamber uses 6 drying trays, 6 electrical motors and 720 kg cashew nuts. Based on the experiment results that had been conducted, it was obtained that the effective motion of the cashew nuts that were being dried occurred at the ratio (r) 0.96. Table 1 shows analysis results that the effective motion for green drying chamber occured at ratio (r) 0.97 – 0.99.

Table 1 Vibrtion for each drying tray

Total mass on a drying tray, M (kg)	Unbalance mass, m (kg)	Rotation speed of electrical motor, n (rpm)	Angular speed, ω (rad/s)	Natural frequency, ωn (rad/s)	Ratio, r (-)	Total mass of cashew nuts, M_{cn} (kg)
140	0.5	175	18.32	18.72	0.97	120
120	0.5	190	19.89	20.22	0.98	100
100	0.5	210	21.98	22.15	0.99	80
80	0.5	235	24.60	24.76	0.99	60

Based on the results of testing was obtained that application of solar energy as the energy resource for the drying only producing drying air temperature less than 60 °C. To dry cashew nuts required air temperature in the drying chamber (Tr) is 60 °C and the analysis result shows that the air temperature in the drying chamber can be achieved if the air temperature after the flat plate heat exchanger (Tc_{out}) is 78.25 °C. Table 2 shows analysis results in this study and also several aquations of the heat transfer [6]. Electrical energy for the mean and infrastructure of the green drying chamber in Buton Island will be fulfilled by converting the water power become an electrical energy by using micro hydro power plant. Table 3 shows the observation and analysis results in this study and also equations of water power and electrical power output [5]. The analysis is obtained that electrical power output more than required electrical energy by a green drying chamber.

Table 2 Heat transfer during the drying time

Heat energy for cashew nuts heating	$q_p = w_o\, cp_k\, (T_r - T_a)$	45112.3 kJ
Heat energy for moisture heating	$q_k = w_i\, (T_r - T_a)$	2534.4 kJ
Latent heat of water	$q_l = (w_i - w_f)\, h_{fg}$	127526.4 kJ
Dry heat quantity	$q_{pg} = q_p + q_k + q_l$	175173.1 kJ (4.87 kJ/s)
Heat loss through walls	$q_w = (\Delta t) / R_T$	25.03 kJ/s
Heat loss by ventilation	$q_v = \dot{m}\, (h + v^2/2)$	87.77 kJ/s
Required heat energy persecond	$q_{th} = q_{pg} + q_w + q_v$	117.67 kJ/s

Table 3 Water Power and Electrical Power Output

Name of River	-	Buton River
Potential Head	H_p	47 m
Capacity	Q	0.9 m³/s
Capacity Design	Q_d	0.35 m³/s
Water Power	$P_h = 9.81\, Q_d\, H_p$	161.3 kW
Efficiency of Turbine, Generator, Mechanical	η_T, η_G, η_M	0.74, 0.85, 0.98
Electrical Power Output	$P_g = P_h\, \eta_T\, \eta_G\, \eta_M$	99.4 kW
Required Electrical Energy by a Green Drying Chamber	P_r	15 kW

4.0 CONCLUSIONS

The effective motion for 120 kg cashew nuts on each drying tray occurred at ratio 0.97 or the angular speed near its natural frequency.

The Required heat energy by a green drying chamber is 117.67 kJ/s and the air temperature in the drying chamber can be achieved if the air temperature after the flat plate heat exchanger is 78.25 °C.

Micro hydro power plant is used to convert the water power become an electrical energy and the obtained water power in this study is 161.3 kW, the produced electrical energy in generator is 99.4 kW while the required electrical energy by a green drying chamber is 15 kW.

The total length of a green drying chamber is 4.83 m and its drying chamber has a dimension of: length 4 m, width 3 m, and height 2 m. Whereas the flat plate heat exchanger has a dimension of: length 0.4 m, width 0.6 m, height 0.3 m and effectiveness is 43 %.

Nomenclature

w_o : Ovendry weight (kg)
w_i : initial water quantity (kg)
w_f : Final water quantity (kg)
h_{fg} : specific latent heat of water (kJ/kg)
R_T : Total thermal resistance
h : entalphy (kJ/kg)
Δt : temperature difference (°C)
v : air velocity (m/s)
T : Temperature (°C)
H : Humadity (%)

Acknowledgement

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