The development of multi-racks clove dryer machine with control of temperature and Relative Air Humidity (RH)

I G Santosa[1], I K E H Wiryanta[1]

[1] Department of Mechanical Engineering, Politeknik Negeri Bali, Kampus Bukit Jimbaran, Bali, Indonesia

E-mail: gedesantosa@pnb.ac.id

Abstract. Clove (*Syzygium aromaticum*, syn. *Eugenia aromaticum*) is one of the leading commodities in Bali. Before it can be processed into a product, cloves must go through a post-harvest process, namely the drying process to obtain a good quality clove. The purpose of this research was to make a multi-rack clove dryer by controlling temperature and relative air humidity (RH). The drying room is designed to have 3 trays with staggered arrangement to facilitate the circulation of hot air in the drying chamber. The hot air produce from a heater and the air flow will circulate using a fan. The temperature and RH sensors were installed in the drying chamber and connected to a control system that will cut off the flow of hot air from the radiator if the desired temperature and RH were reached. The results showed that the design of the drying machine that has been made can work properly. The hot air produce from the heater can circulate and the heat air on the staggered racks arrangement evenly distributed. The decreasing of clove mass per tray are about 40 percent after drying with the decreasing of clove's water content about 44 percent.

1. Introduction

Clove is one of the leading commodities in Bali with a total land area of around 15,355 ha, and production reaches 3,126 tons per year [1]. Cloves are widely used as spices, both in their intact form or as powder. Before it can be processed into a product, cloves must go through a post-harvest process, which was the drying process to obtain a good quality clove, this drying processes must be done as soon as possible after harvesting because the delay in drying can adversely affect the quality of cloves. The good qualities of cloves based on The Indonesian National Standard (SNI 01-3392-1994) are containing 14% of water [2]. There is why the drying process of cloves takes the most important thing in the post-harvest process of the cloves.

The drying process of fresh harvesting cloves can be done by two different ways. The first and most common use by a farmer were drying the cloves under direct sunlight. The other ways are using an artificial machine to processes the drying. Some research of making a drying machine has been done. A review on the application of a tray dryer system for agricultural products has been done to find the most effective and accurate dryer system [3]. Another type of dryer has also made and builds by some researcher. A design and fabrication of rotary hot-air dryer to increase the value of fruit waste has been made by [4]. The result showed the optimum drying conditions for citrus fruit waste was at 60 ˚C temperature, 1m/sec air flow rate and 40 rpm of drum speed. The drying process took 200-220 minutes to reach to moisture content below 10%. Improvement on the design of a cabinet grain dryer has been

done by [5]. The drying chamber has a length of 0.8 m, width of 0.8 m and height of 1.2 m. heated air of about 35-40 °C blown across the grains. Heat was supplied by an electrical heating coil and hot air was blown from the heater housing to the drying chamber by the aid of a fan. As the result showed the improvement of design made the drying faster and grains are moderately dried. Other types of dryer made by [6-11] with modification in drying chamber, tray design and also the heat source of dryer machine. All of the previous works have same purpose, which is build an ergonomic, effective dryer machine to help farming post-harvest processes.

Based on the description above, it is interesting to design and build a clove dryer machine with a control system for temperature and relative humidity. Thus drying of cloves is expected to be more precise and optimal, where the clove water content after going through the drying process is in accordance with the SNI standard of clove quality, which is around 14% of the water content.

2. Methodology

The development of clove dryer machine with control of temperature and relative humidity were divided into two sections. The first was creates a design of the dryer machine, and the second was fabrication or build the clove dryer machine.

2.1. Design

The design of the clove dryer machine shown in Figure 1 below:

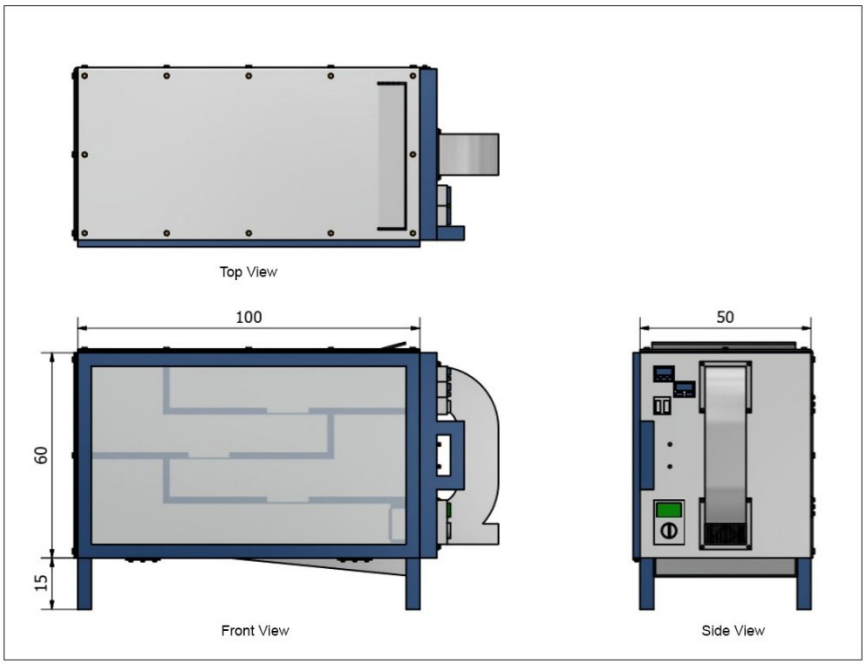

Figure 1. Design of clove dryer machine.

The clove dryer machine designed has a 3-sieve tray made from stainless plat. The hot air from a heater blows into the drying chamber by a fan with various rates. The temperatures and relatives air humidity in the drying chamber controlled by using a thermostat and humidifier. The hot air outlet the drying chamber will circulates using a ducting so the heat energy will not waste. The wall of dryer also insulated to prevent the heat loss. The schematic of composite wall of the drying chamber are shown in Figure 2 below:

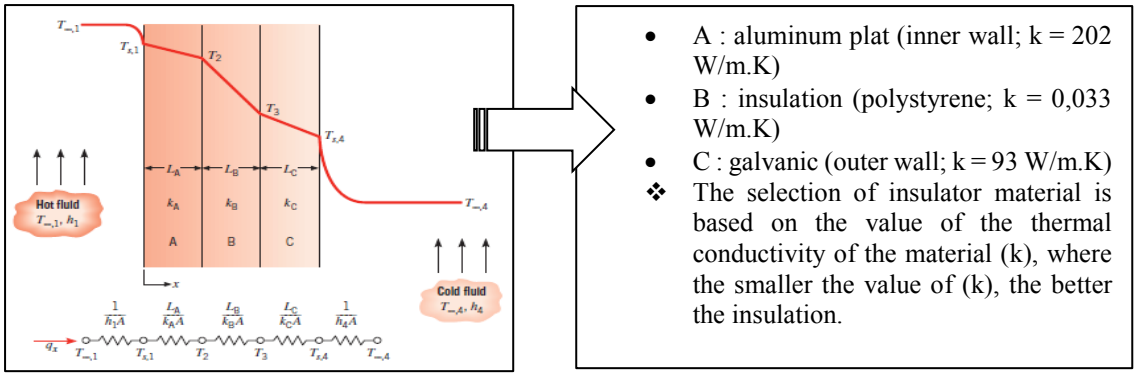

Figure 2. Design of composite wall of drying chamber.

The heat transfer rate from inside of the drying chamber across the composite wall can be expressed by equation: [12]

$$q' = U.A.\Delta T \quad (1)$$

$$U = \frac{1}{R_{tot}A} = \frac{1}{[(1/h_1) + (L_A/k_A) + (L_B/k_B) + (L_C/k_C) + (1/h_4)]} \quad (2)$$

Humidity is a level of state of the wet air environment caused by the presence of moisture or moisture in the air. Dew is a very small H2O particle that fills air volume [12]. To find the optimum result of drying time, a sensor is installed in the drying chamber which shows the temperature and also the relative humidity (RH) of the clove in drying chamber.

2.2. Fabrication/builds of clove dryer machine

The clove dryer machine was built according to the design in Figure 1 above. The cloves dryer chamber has 3 identical sieve trays made from aluminium plate. A ceramic electric heater uses as the source of hot air, and it's blown into the drying chamber using a fan. The heat transfer analysis to obtain the heater's power from equation 1 and 2 above give the result that the heater must have a minimum power 667.91 watt. Outlet of the drying chamber, the hot air will circulate again into the drying chamber through a ducting. It is to prevent the waste of energy.

Figure 3. The clove dryer with 3 sieves.

The specification of the clove dryer machine that was build shown in Table 1 below:

Table 1. Clove dryer specification.

Name	Specification
Dimension (p x l x t)	100 cm x 50 cm x 75 cm
Number of trays	3
Tray geometry	Aluminium plat Square with sieve (71 cm x 50 cm)
Tray arrangement	Staggered Gap per tray 11 cm Pitch to wall 21 cm
Heater	Ceramic electric heater 750 watt
Fan	125 watts
Wall	Aluminium plate (inner wall) Galvanize (outer wall) Insulation: polystyrene, thickness 2 cm
Ducting	Aluminium plate

3. Results and discussion

3.1. Experimental analysis

The experimental investigation was observed from the clove dryer. The hot air as the heat source of dryer produce by a heater and blown a forced convection from a fan the fan with a flow rate of 2.8 m/s. The temperature of the drying chamber, temperature of the tray observed using a K-type thermocouple. The temperatures of the clove dryer controlled by a thermostat and maintain between 50°C - 60°C. The process of clove drying as the test for the clove dryer machine shown in Figure 4 and Figure 5 below:

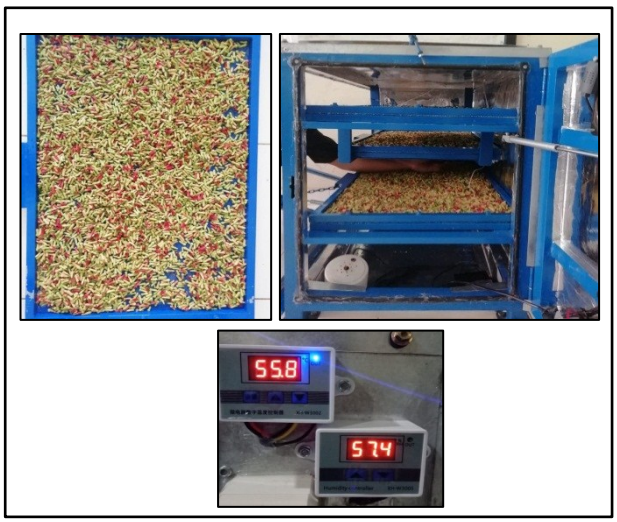

Figure 4. Process of clove drying using the clove dryer.

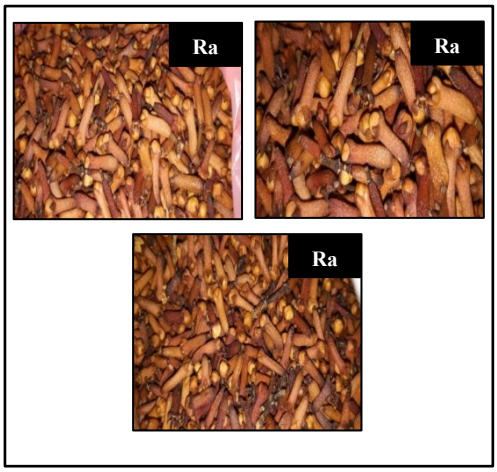

Figure 5. Clove after processes in dryer.

The result of performance test of the clove dryer machine shown in Table 2 below:

Table 2. Clove dryer performances.

Time (minutes)	Temperature (°C)			RH
	Rack I	Rack 2	Rack 3	
0	28.8	29.5	32.3	80.9
30	44.1	45.5	48.1	69.7
60	53.3	54.1	55.8	53.2
90	56.3	57.1	58.6	66.7
120	56.3	57.3	58.3	66.1
150	56.4	57.5	58.5	64.4
180	56.5	58.2	58.6	64.2
210	56.7	58.5	58.9	63.2
240	56.3	59.1	58.9	63.2
270	56.5	59.2	58.8	62.6
300	56.3	59.3	59	61.5
330	55.7	59.4	58.4	60
360	55.8	59.5	58.3	58.4

The result of clove's mass and water content are shown in Table 3 below.

Table 3. Drying result.

Mass (kg)						Water Content (%)					
Rack 1		Rack 2		Rack 3		Rack 1		Rack 2		Rack 3	
before drying (m0)	after drying (m1)	before drying (m0)	after drying (m1)	before drying (m0)	after drying (m1)	before drying (Wc0)	after drying (Wc1)	before drying (Wc0)	after drying (Wc1)	before drying (Wc0)	after drying (Wc1)
1.5	0.8	1.5	1	1.5	0.9	50	28.1	50	28.8	50	28.5

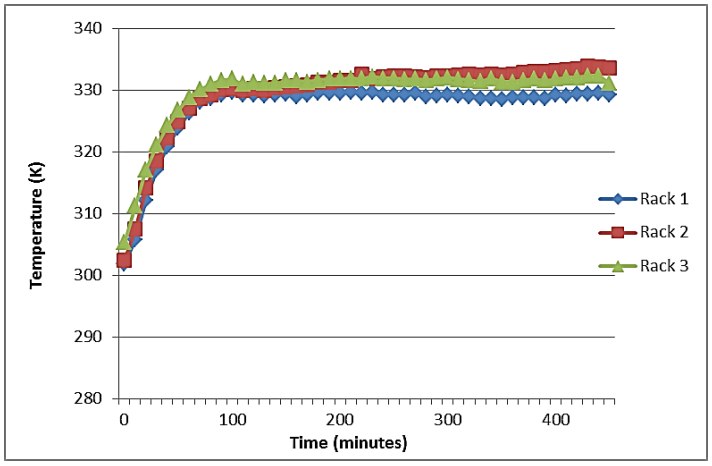

Figure 6. Temperature distribution.

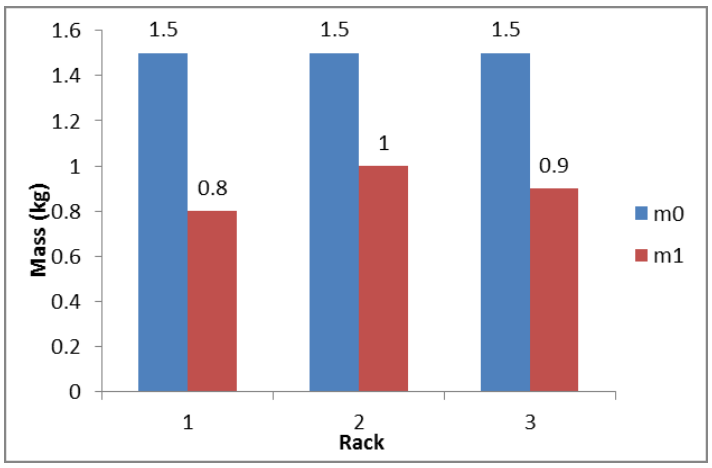

Figure 7. Mass of cloves.

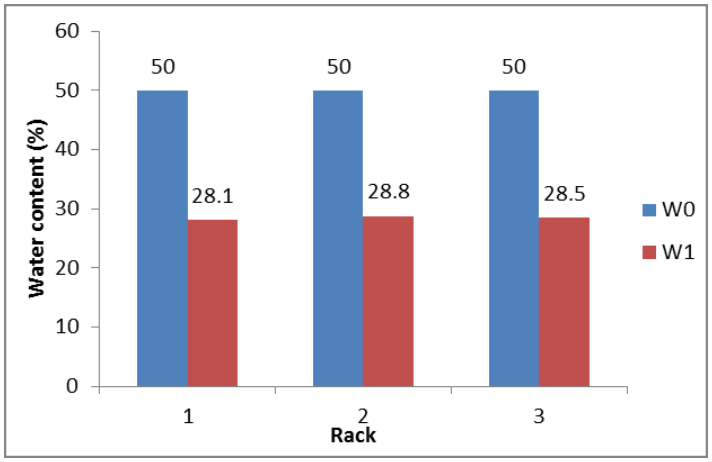

Figure 8. Water content of clove.

Figure 6 above shows that at the temperature of drying chamber at each rack evenly distributed. Temperatures control in drying chamber work very well, where the highest temperatures were on the third rack in drying chamber. Figure 7 and Figure 8 show the test result for drying clove before and after drying process. The mass of clove after drying process decreasing about 40% and the water content of cloves after drying decreasing about 44 %.

4. Conclusions

From the foregoing analysis, it can be concluded that clove dryer that has been design and build with 3 staggered racks with controlling the temperature and relative air humidity in the drying chamber can work properly. The result showed that the drying of the clove uniform for different tray, that described hot air in the drying chamber distributed properly. The decreasing of clove mass per tray are about 40% after drying with the decreasing of clove's water content about 44%.

From the results of experimental it can be suggested several things to improve the clove dryer performances. The first is an improvement on the system design, including the material of clove dryer, tray and insulation.

5. References

[1] Dinas Perkebunan Provinsi Bali 2016 *Komoditi Unggulan Perkebunan Provinsi Bali*
[2] Badan Standarisasi Nasional 1994 *Standar Mutu Cengkeh* (Jakarta: Badan Standarisasi Nasional Cengkeh)
[3] Misha S S Mat, M H Ruslan, K Sopian and E Salleh 2013 *World Applied Sciences J.* **22** 424-433
[4] Jamil F, Rizwan A and Muhammad A Ali 2018 *Earth Sciences Pakistan (ESP)* **2** 7-11
[5] Stephen A K and Seckley E 2009 *American J. of Engineering and Applied Sciences* **2**
[6] Phoungchandang S, S Nongsang and P Sanchai 2009 *Drying Technology: An Int. J.* **27** 1123-1131
[7] Liu H, Khurram Y, Kunjie C, Rui F, Jiaxin L and Shakeel A L 2018 *Sustainability* **10** 3216
[8] Solano E M V and Fredy A G R 2010 *Ingeniería E Investigación* **30**
[9] Gupta P M, Amit S D, Ranjit C B, Sagar C P and Vishal G P 2017 *Int. Research J. of Eng. and Tech. (IRJET)* **04**
[10] Balbine M, Edoun M, Kuitche A and Zeghmati B 2015 *Int. J. of Energy Engineering* **5** 80-86
[11] Rahimi R, Maryam M S and Elahe B 2012 *Chemical Engineering Science* **76**
[12] Incropera F P, David P D 2011 *Fundamentals of Heat and Mass Transfer* (New York: John Wiley & Son)

Acknowledgment

The authors would like to acknowledge The Director and Head of P3M State Polytechnic of Bali for funding this research. The authors also like to thank full to the research team and all the staff of Mechanical Engineering Department of State Polytechnic of Bali for the support.