

The effect of fluid flow variation on clove dryer machine with control of air temperature and relative humidity

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Abstract. In this study, the heat effectiveness and energy efficiency of the clove drying machine with control of temperature and relative air humidity were analysed. The data were carried out experimentally on a clove dryer machine that has 3 racks with staggered arrangement by varying the speed of the air flow into the drying chamber. The hot air produced from a heater and blown to the drying chamber used a fan with 3 various speed rate (1.9 m/s, 2.3 m/s, 2.8 m/s). The heat distribution on each rack was observed and analysed and compared with the energy requirements of the machine. The result showed that the heat flow on the rack evenly distributed. The fluid flow variation has the important effect. The heat will more effective with the lower air flow speed, which the higher heat transfer (q) to the clove from the heater depend on the air flow speed with the higher value 72.78 watt at the lowest positions rack with hot air speed 2.8 m/s. The energy efficiency of the machine was about 37 percent, with the highest value 39.27 percent at the air speed 2.3 m/s.

1. Introduction

The drying process of fresh harvesting cloves takes the most important thing in the post-harvest process of the cloves to reduce the water content of the cloves, which according to The Indonesian National Standard (SNI 01-3392-1994) the good quality of cloves are containing 14% of water [1]. The drying process of cloves can be done by two different ways. The first and traditional ones were drying the cloves under direct sunlight. This was the most common process used by the farmer. The second ways were using an artificial machine to help the drying processes.

Some research of making a drying machine has been done with various type of heat source, drying chamber design and material. Experimental evaluation of thermal performance of dryer has been done by varying the airflow configuration. The result showed the higher hot air temperature led to the faster drying rate and the shorter drying time. For vertical airflows batch drying the efficiency were 17%, 18% and 22% respectively at 40°C, 50°C and 60°C. In the case of vertical counter current airflows drying those efficiency were 34%, 25% and 22%. [2]. Another investigation of the effect of drying temperature and drying air velocity on the drying rate and drying constant of cocoa bean has been done. Three levels of temperatures (55, 70 and 81 °C) and three air velocity levels (1.3, 2.5 and 3.7 m/s) were used and the result showed that the drying rate increased with increase in temperature and air velocity, however decreased with time. [3]. This study was about drying rate and the efficiency was done numerically. A mathematical model for predicting drying rate of cocoa has been done. The results obtained showed that



moisture content decreased as drying time progresses for each temperature regime due to the increase of vapor pressure in the samples, which resulted in an increased diffusion rate of the internal water [4]. The effects of holes diameters on the tray hydraulic and on the mass transfer were investigated using CFD modelling. It has been concluded that the tray with smaller holes diameters would give more uniform liquid phase mixture, lower back mixing and higher efficiency [5]. The other research and investigations to the efficiency of drying machine also made by modifying the design of tray, drying chamber, heat source and the materials [6 - 10]. All the improvements of the previous research has same purpose, which was build an ergonomic, effective and efficient dryer machine to help the farmer in post-harvest process.

Due to the description about drying analysis above, it is interesting to find the accurate relations between drying performances of clove dryer machine by varying the airflow into the drying chamber. Thus drying of cloves was expected to be more precise and optimal, in time, energy efficiency and give a good quality to the cloves where the clove water content after process going through the drying process is in accordance with the SNI standard of clove quality.

2. Methodology

The experimental analysis to the effect of fluid flow variation on clove dryer machine was carried out on the drying chamber with 3 staggered rack arrangement and controls of temperature and relative air humidity. The hot air produced from an electric ceramic heater, and blown to the drying chamber by a fan with 3 speed rate (1.9 m/s, 2.3 m/s, 2.8 m/s). The temperatures of drying chamber controlled between 50°C - 60°C using thermostats. The RH were maintain at 20% by using a humidifier. The hot air outlet the drying chamber will circulates using a ducting therefore the heat energy will not waste. The wall of dryer also insulated to prevent the heat loss. The temperature at each rack observed using K-Type thermocouple, and the energy consumption observed using digital VCPE.

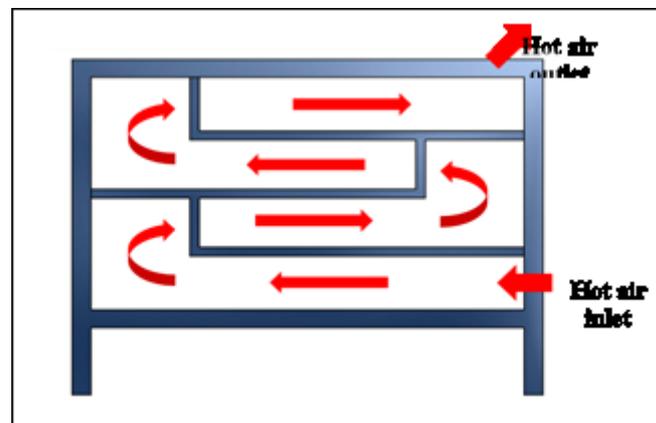


Figure 1. Air flow schematic in drying chamber.

By assuming the racks are a flat plate, the heat transfer rate (q) from the hot air into the cloves calculates using the governing equation below [11]

$$q = h \cdot A (T - T_0) \quad (1)$$

Where:

T = Temperature of rack

T_0 = Initial clove temperature

To find the value of h (heat transfer coefficient) using the equation:

$$h = \frac{Nu \cdot K}{L} \quad (2)$$

Where:

$$Nu = 0.664.Re^{0.5}. Pr^{1/3} \quad (\text{laminar flow}) \quad (3)$$

$$Nu = 0.0296.Re^{0.8}. Pr^{1/3} \quad (\text{turbulent flow}) \quad (4)$$

To determine the flow regime used the equation for Reynolds Number (Re):

$$Re = \frac{V.L}{\nu} \quad (5)$$

3. Results and discussion

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 1.9 m/s, 2.3 m/s, and 2.8 m/s. The fresh cloves evenly placed on each rack with the weight of 1.5 kg. The heat transfer rate (q) from the hot air into the cloves calculates using governing equation above. The result of the clove dryer performances shown in Table 1, Table 2, and Table 3 below:

Table 1. Clove dryer performances (V = 2.8 m/s).

No	Time (minutes)	Temperature (K)				q (watt)			P (watt)	ε (%)
		T0	Rack 1	Rack 2	Rack 3	Rack 1	Rack 2	Rack 3		
1	0	300.8	329.1	303.9	306.7	77.26	8.52	16.19	538.7	18.93
2	30	300.8	326.5	313.3	319	70.19	34.24	49.78	507.5	30.38
3	60	300.8	329.6	335.2	321.4	78.62	93.85	56.31	510.2	44.84
4	90	300.8	329.6	335.7	321.2	78.62	95.21	55.77	508.1	45.19
5	120	300.8	328	325.3	321.3	74.27	66.93	56.04	510	38.67
6	150	300.8	327.8	324.8	320.6	73.72	65.56	54.13	502.5	38.49
7	180	300.8	327.4	324.6	320.3	72.64	65.02	53.32	513.6	37.18
8	210	300.8	327.8	325.2	320	73.72	66.65	52.50	507.6	38.00
9	240	300.8	327.4	325.6	320	72.64	67.74	52.50	507.3	38.02
10	270	300.8	327.6	325.9	320.1	73.18	68.56	52.77	508	38.29
11	300	300.8	328.5	326	320.7	75.63	102.18	54.41	509.4	45.59
12	330	300.8	329.1	327.3	321.1	77.26	72.37	55.50	502.6	40.81
13	360	300.8	329.6	327.5	321.2	78.62	72.91	55.77	500.9	41.38

Table 2. Clove dryer performances (V = 2.3 m/s).

No	Time (minutes)	Temperature (K)				q (watt)			P (watt)	ε (%)
		T0	Rack 1	Rack 2	Rack 3	Rack 1	Rack 2	Rack 3		
1	0	300.8	310.4	299.7	300.9	23.85	-2.74	0.25	425.4	5.02
2	30	300.8	319.9	316.7	314.9	47.34	39.43	34.99	415.7	29.29
3	60	300.8	326.9	324	321.9	64.60	57.45	52.27	407.9	42.74
4	90	300.8	328.3	334.9	322.7	68.05	84.32	54.24	414.2	49.88
5	120	300.8	329.1	326	323.3	70.02	62.38	55.72	438.2	42.93
6	150	300.8	330.1	326.9	324.3	72.49	64.60	58.19	435.4	44.85
7	180	300.8	330.7	327.1	325	73.97	65.09	59.92	445.2	44.69
8	210	300.8	331.3	327.7	325.3	75.44	66.57	60.66	430.3	47.10
9	240	300.8	331.3	328.4	326.1	75.44	68.30	62.63	432.5	47.72
10	270	300.8	332.4	329.1	326.1	78.16	70.02	62.63	436.7	48.27

11	300	300.8	333.1	329.3	326.8	79.88	108.69	64.35	426.2	59.34
12	330	300.8	324.2	330.1	327.4	57.94	72.49	65.83	466.4	42.08
13	360	300.8	334.4	330.5	327.3	83.08	73.47	65.59	413.3	53.75

Table 3. Clove dryer performances ($V = 1.9$ m/s).

No	Time (minutes)	Temperature (K)				q (watt)			P (watt)	ϵ (%)
		T0	Rack 1	Rack 2	Rack 3	Rack 1	Rack 2	Rack 3		
1	0	300.8	305.8	305.7	307.8	11.31	11.08	15.82	425.4	8.98
2	30	300.8	324.3	319.5	319.3	52.89	42.13	41.68	415.7	32.88
3	60	300.8	328.6	324.3	323.7	62.52	52.89	51.54	407.9	40.93
4	90	300.8	329.6	325	324.2	64.76	54.46	52.66	414.2	41.50
5	120	300.8	329.2	322.6	321.4	63.87	49.08	46.39	438.2	36.36
6	150	300.8	329.2	321.3	320.9	63.87	46.16	45.27	435.4	35.67
7	180	300.8	329.4	320.6	320	64.32	44.59	43.25	445.2	34.18
8	210	300.8	320	320.5	319.6	43.25	44.37	42.35	430.3	30.20
9	240	300.8	278.8	320.8	319.5	-50.46	45.04	42.13	432.5	8.49
10	270	300.8	331.3	320.9	319.4	68.57	45.27	41.90	436.7	35.66
11	300	300.8	332.7	321.6	319.2	71.71	65.91	41.45	426.2	42.02
12	330	300.8	333.1	321.9	319.1	72.60	47.51	41.23	466.4	34.59
13	360	300.8	332.8	322.2	319.1	71.93	48.18	41.23	413.3	39.04

The performances of clove dryer machine as the test for clove drying processes are shown in Figure 2 and Figure 3 below:

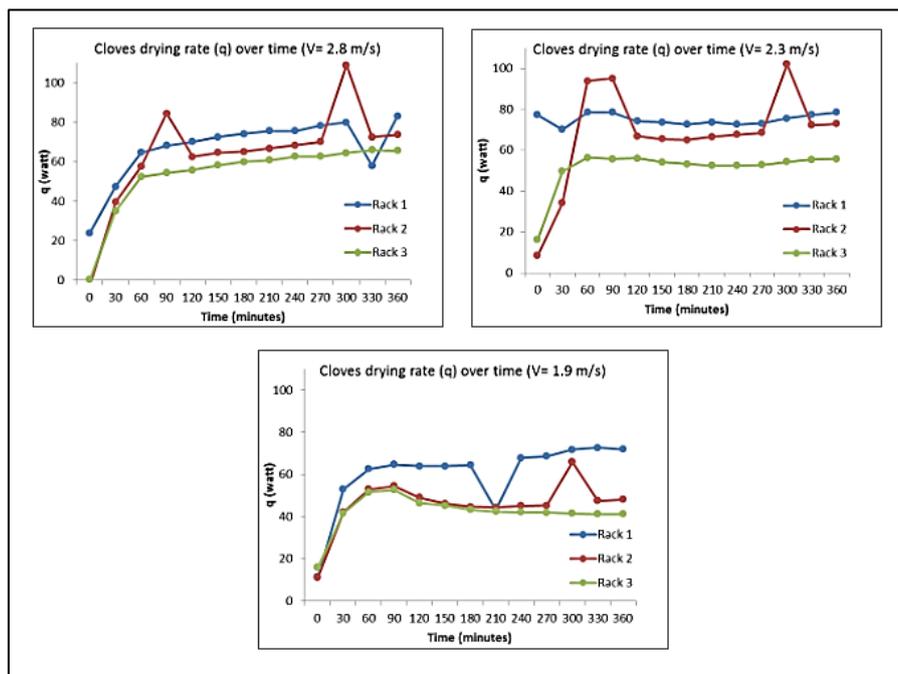


Figure 2. Clove drying rate over time.

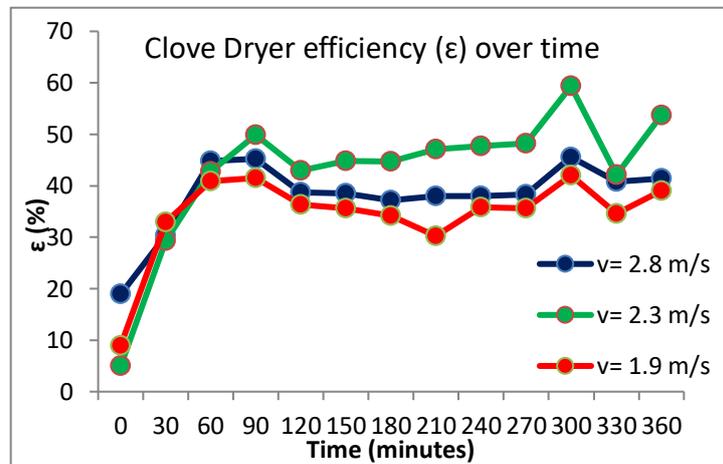


Figure 3. Clove dryer efficiency over time.

The analysis of the drying rate of the clove over time during the process shows in Figure 3 above. The result shows at the beginning the drying rate increasing, because at the beginning the drying chamber just begun heated. The temperature controls of drying chamber take an advantage to stabilize the clove drying rates. The clove drying rate (q) will tent to stable after 60 minutes of heating with the values about 64 watt for the air flow rate 2.8 m/s, about 60 watt for air flow rate 2.3 m/s, and about 50 watt for air flow rate 1.9 m/s. This indicated that the heat transfer rate from the air into the cloves fully influenced by the air flow rate. The rack positions also take important things during the drying process, due to the staggered alignment of the rack will cause the fluctuating air flow near the wall and the buoyancy effect of the hot air the higher rack will take the lower heating process. It shown by Figure 3 above, where the third rack (higher rack) always have the lowest value of drying rate for all air flow rate variation. The highest value of drying rate during the process was 75.11 watt at the first rack (lowest rack) with air flow rate 2.8 m/s.

From Figure 3 above, the average efficiency of clove dryer machine (ϵ) were analyzed. The efficiency calculates by comparing the total drying rate (q) with the energy consumption. The analyzed shows that the most efficient process obtained at air flow rate 2.3 m/s with the value ϵ about 42.9 % and the highest efficiency were 59.34 %.

4. Conclusions

From the analysis of the result on the clove, the clove drying rate showed different values due to the variation of the air flow rate. The lower the flow rate also caused lower drying rate to the cloves. From the result, the average drying rate of the cloves were about 64 watt for the air flow rate 2.8 m/s, about 60 watt for air flow rate 2.3 m/s, and about 50 watt for air flow rate 1.9 m/s. The rack position also take an important placed to the drying rate of cloves, which the lowest rack (first rack) always have the highest values of drying rate for all the air flow rate variations. The cloves dryer machine efficiency has the average value about 38.17 % for air flow rate 2.8 m/s, about 42.9 % for air flow rate 2.3 m/s, and about 34.45 % for air flow rate 1.9 m/s. From the results of experimental it can be suggested several things to improving the clove dryer performances. The first is an improvement on the system designs, including the material of clove dryer, tray and insulation. The second is improvement of the controls, therefore the clove drying process can controlled full automatically.

5. References

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