Effect of airflow on Heat Pump in drying mode

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Abstract. Manufacturers develop new technologies to process sensitive food materials to supply new products with improved properties and high quality. Heat pump technologies for drying can contribute to increased productivity, product quality, environmental and energy-saving benefits. Development of heat pump increase to decrease the drying time. A heat pump has been designed and fabricated. This paper improves the drying process with a variance air flow of the heat pump. During the experiment, the temperature, and relative humidity of hot drying air was the measure. The heat was analysed during the drying experiment. The result showed that the airflow of the drying has a high impact on drying. The temperature on the drying are plotted. This fact suggests that the direct contact on surface commodity, made the temperature on commodity has high.

1. Introduction
In many parts of the world, awareness about the use of appropriate technology which has an important role for farmers in developing countries like Indonesia to increase their productivity. Especially, Indonesia has a tropical climate. Base on BMKG research, average temperature in Indonesia is 27-30 °C and 50-70% of humidity [1]. Although Indonesia is one of the best producers of fruits and vegetables. Widely of fruits and vegetables produces in Indonesia go to waste rotten to improper postharvest and the lack of nest processing. This result in a large gap between gross food production, storage, and net availability. Reduction of postharvest losses is important to increasing food availability from existing production. Some of traditional techniques used in preservation to maintain food quality are drying, refrigeration, freezing, salting (curing), sugaring, smoking, pickling, canning, and bottling. Among these, drying is one of the choices for developing countries because of low cost, easy to apply, and practical means preservation on reducing postharvest losses [2].

Drying method means reducing the moisture content from food, drying process can preventing bacterial growth and maintain the quality characteristic of the product under drying [3]. Drying is the simple process of dehydrating foods until there is not enough moisture to support microbial activity. This method is still used in home drying up to commercial drying. Some of method for drying was used heat pump, heater with electricity, smoking, and solar. One of dryer method is utilized of heat pump for drying. Heat pump technology are the energy saving potential and the ability to control drying temperature and air humidity [4].
Some of research about heat pump for drying process has studied. Minea [5] modification the heat pump drying process with internal heat exchanger to improvements the temperature for wood drying process. Ivan Zlatanovic et al. [6] investigated the efficiency of heat pump drying system with full air recirculation. The material was drying as apples, potatoes, and bananas. The efficiency of the heat pump drying system was analyzed as moisture extraction rate, and energy consumption. Himsar Ambarita et al. [7] examine the performance of heat pump clothes dryer with the addition of flat plate heat exchanger. The result showed that Heat pump clothes drier can produce a high drying rate because there is a role evaporator as lowering humidity. Woohyun and James [8] evaluated the impact of refrigerant charge on heat pump performance. The refrigerant charge level used approximately 30 to 150% and this study indicated that improper refrigerant charge amount can reduce the efficiency of systems by 15% in the field. Romauli and Himsar Ambarita [9] studied the effect of convective drying. The study forced convective drying of potato cube has been carried on experimentally. The hot air was directly contact on surface of potatoes.

In this present work, the characteristic of dried with pure heat pump system is investigated. The good drying is determined by the drying rate indicated by the high temperature and low humidity in the dryer. So, one chance is to modify the airflow of the heat pump. To increase the temperature in the drying tray. The main focus will be the comparison of airflow of the heat pump system. Here the heat pump drier is optimized by varying the heat flow to the drying box. The result of this study provides important information related to the development of the drying system.

2. Method
The method used to determine the drying process on the material was investigates through experiments. The experimental equipment is presented in figure 1. It consists of four main components, they are vapor compression cycle unit, drying box, trays, and measurement apparatus. The commodity which will be dried was placed in the drying box. The dimension of drying box is 100 mm x 100 mm x 80 mm This drying experiment was carried out by passing out hot air over the drying trays. The drying box was wrapped in insulation and experiences no heat losses. The temperature, velocity and humidity in the drying box was record with data logger.

![Figure 1. Experimental apparatus](image)

The data logger was design to experimental apparatus. It consists of Agilent data logger to measure temperature of the commodity; the humidity of the drying box is measured using hygrometer data logger and the wight of the commodity is measured using load cell data logger. The drying experiments were
carried out using an effect of direct and indirect heat from vapor compression cycles unit. The drying process were operated closer to the drying box side under forced convection by wind power induced blower. Figure 2 showed that ways of air flow drying heat pump. There is two-way air flow was tested as the experimental. Firstly, the air flow from sideways of drying box, and secondly from the bottom ways drying box. In this study the main commodity was test is chili. Were put on trays with dimension 50 mm x 50 mm x 20 mm. One load cell was put to record decrease the load of commodity and two thermocouples are place to the commodity to record the temperature and humidity of commodity.

![Image](attachment:figure2.jpg)

(a) ![Image](attachment:figure2.jpg)

(b)

**Figure 2.** Variance of air flow the drying heat pump (a) side flow; (b) bottom flow

3. Results

There are two different air flows inlet on the drying box of the heat pump. Firstly, the airflow on the side of the drying box, and the second is the airflow from the bottom of the drying box. The experiment result will be analysed in terms of characteristics of the temperature of the heat pump. The profile of drying air inlet from vapor compression cycle unit to drying box is presented in figure 3. In this experiment the temperature inlet, relative humidity, and temperature on the tray was record. The velocity of hot drying air from vapor compression cycle was constant as the experiment equal to 2.6 m/s.
Figure 3. Profile of temperature and relative humidity inlet to drying box on a heat pump

In the figure 3, the temperature of the drying air inlet to drying box is shown by the red line, and relative humidity is shown by the blue line, respectively. The figure shows that in the beginning, the temperature inlet on the drying box starts from temperature, about 46 °C, increasing gradually to 59 °C. After reaching the maximum temperature, it is constant during the experiment. At the same time, increasing temperature followed by decreasing the relative humidity. It is starting at 37.9 % and finally reaching 27.5 % relative humidity.
Profile temperature of the trays of drying box on heat pump is shown in figure 4. The experiment has measured temperature on the surface of a tray with thermocouple, which is put down the commodity to be would be dried. The air flow from sideways it shown on figure 4.a. The figure shows that in the beginning, the temperature inlet on the drying box starts from temperature, about 35°C, increasing gradually to 48 °C, and the average of temperature on tray is 45.1 °C. While the air flow from bottom ways it shown on figure 4.b. The figure shows that in the beginning, the temperature inlet on the drying box starts from temperature, about 44.5 °C, increasing gradually to 54.9 °C, and the average of temperature on try is 51 °C.

From both graphs, the temperature on tray 2 where the airflow from the bottom has higher than tray 1 where the airflow from the sideways. This is because the hot air from the vapor compression cycle to have direct contact with the surface of the commodity on tray 2. It made the temperature on a commodity on tray 2 has higher than tray 1. Where it did not happen on tray 1. On tray 1 when the hot air inlet to drying box, the airflow firstly contacts the sidewall of the tray. It made the temperature on the tray not equally different from tray 2, the hot air contact direct to tray as a commodity because the bottom of the tray was perforated. So, when the temperature on the commodity higher it made the moisture content on the commodity decrease rapidly.

4. Conclusions
This paper focuses on methods allowing improving the design of heat pump dryer. The variance of airflow of hot drying air from vapor compression cycle has been done analysed. The inlet velocity of hot drying air was constant during the experiment. The result showed that the airflow of the drying has a high impact on drying. This experiment suggests that direct contact on surface commodities, made the temperature on commodity has high. The experimental data of the present work can be used to accelerate the drying process.

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