Performance analysis of rack type solar dryers with mass variations of dried material and types of fins

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Abstract. The purpose of this study was to determine the performance of solar dryers based on effect of variations on mass of dried material and effect of types of fins. The air flow in the solar dryer is a natural convection. Solar dryers used in this study were four solar dryers of rack type which has three stacking shelves with different type of fin respectively. Testing method that used was direct simultaneous testing. The material that was dried was corn. Testing of the first day was conducted with an initial material mass of 500 grams/rack while the second day used 900 grams/rack. Testing were conducted in the city of Makassar, South Sulawesi, Indonesia, from 10:00 am until 16:00 pm. Testing with the initial mass of material of 900 grams/rack had greater drying rate and efficiency but the decline in water content was lower than the testing with initial mass of material of 500 grams/rack. Based on the decrease in water content, drying rate and efficiency, the use of a large wave fin had the best performance and almost the same with the zigzag fin. The use of a small wave fin had the lowest performance while the plate fin slightly better than the small one.

Keywords: fin, the mass of material, solar dryer, rack type, natural convection

1. Introduction
Plantation products require post-harvest handling. The post-harvest handling is needed to extend life of plantation products to prevent rapid deterioration [1]. One of methods of the post-harvest handling is drying process. Without the drying process farmers can get loses up to 40% [2]. There are several energy resources used in the drying process. One of the energy resources is widely used is solar energy. Solar energy is a renewable alternative energy [3] so that the utilization of solar energy grows fastly mainly in areas that have high solar energy. Indonesia is a tropical country that has a very large potency of solar energy [4].

Utilization of solar energy for the drying process requires solar dryer equipment. One of models of the solar dryers is a rack type [5-8]. Advantage of the solar dryer of rack type is capable for drying materials in large quantities. There are many efforts to improve the performance of solar dryer rack type, including the use of gravels [5], fins [1] and plates [7] as heat storage. Performance improvement can also be done by providing a forced convection flow [6] and the use of wind ventilator [8]. All agricultural products can be dried in a solar dryer rack type, in many studies, various agricultural products that have been dried are chili [5], eggplant [6], maize [7, 1], bananas [9] etc.

One of factors that affect the performance of the solar dryer rack type is convection air flow in the drying chamber. There are two types of convection air flow namely natural convection [10, 11] and forced convection [12, 13]. Forced convection flow can increase the drying rate [14] but it requires electrical power whereas natural convection flow does not require electrical power but the
performance is not optimum. This study seeks to optimize the flow of natural convection to increase the rate of the dryer.

The use of fins is one way to improve the performance of solar dryers. Fin serves to increase heat absorption area [15] without increasing dimensions of the solar dryer. Research that conducted was an attempt to optimize the performance of the solar dryer rack type with the influence of the mass of material that was dried and the use of various types of fin.

2. Methodology

The material that be dried in this study was corn. Tests on the first day were done with the initial mass of material be dried was 500 grams/rack or 1.5 kg for each solar dryer with the initial moisture content of 78.41%. Tests on the second day were done with the initial mass of material be dried was 900 grams/rack or 2.7 kg for each solar dryer with the initial moisture content of 79.10%.

Fins used in this study were made by zinc material with a thickness of 1 mm. The tests used four types of fin namely small wave, big wave and zigzag plate. The types of fin can be seen in Figure 1. All fins dimensions were 600 mm x 1090 mm except the height of the fins. The similarity of the four types of the fin was the same dimensions when stretched to form of sheets straight plate.

![Figure 1. Various types of fins (a) small wave (b) big wave (c) plate and (d) zigzag.](image)

Testing scheme can be seen in Figure 2. The intensity of solar radiation entering the room through the glass cover of solar dryers so that temperature of the air in the drying chamber increased. The increase in temperature caused the air had a lower density so that the air becomes lighter [15] and moved towards the drying chamber. The movement of air due to the temperature difference is called the natural convection [15]. The air that moved up and replaced by outside air that entered through the channel of inlet. The outside air was dry air. The hot air in the drying chamber caused the drying process occurred in the material so that the water vapor came out through the material caused the air becomes humid and its density is greater. The humid air would drain out through the channel of water vapor. The air that was on the top of the drying chamber would come out through the air outlet so that the natural air flow could be occurred which increased the heat transfer rate [15].

There are four innovations in this study which were effort to increase the drying rate namely the use of fins to increase the heat transfer area so that accelerated the rate of heat transfer. The use of the inlet channel to keep the air in the drying chamber remained the dry air. The use of the channel of water vapor to dispose of moist air so the air remained the dry air. The use of the channel of outlet kept the natural convection flow persisted.
Tests of the solar dryer rack types were done simultaneously for the four types of fins that can be seen in Figure 3. The tests were done in order to obtain accurate results. As for test with various of the initial mass of material performed on different days with sunny weather conditions. The tests conducted in Makassar, South Sulawesi, Indonesia. The tests were conducted at 10:00 am until 16:00 pm. Data were collected at the beginning of the test and every 1 hour.
3. Results and discussion

Intensity of the solar radiation and ambient temperature at the time of the testing can be seen in Figure 4. The intensity of the solar radiation on the first day (testing with a mass of material 500 grams/rack) was slightly larger than the intensity in the second day (testing with a mass of material 900 grams/rack), as well as the ambient temperature on the first day was slightly larger than the second day. Maximum intensity of the solar radiation and ambient temperature occurred at 12:00 until 13:00 pm.

![Figure 4. Solar intensity and ambient temperature when testing.](image)

![Figure 5. Decreasing of the mass of material on each shelf with initial mass of 500 g/rack using various types of fins (a) Small Wave (b) Big Wave (c) Plate (d) Zigzag.](image)
Figure 5 shows that the decreasing of the mass of material in the drying process with the initial mass of 500 grams/rack. The biggest material mass reduction occurred on the bottom shelf because the bottom shelf of the rack firstly received the hot air. The material mass reduction on the top shelf was greater than on the middle shelf when the fins of plate and zigzag were used. Furthermore, in the use of the small wave fins, decreasing of the mass of material on the middle shelf was greater than the top shelf. The use of the large wave fins provided the same reduction in the mass of material between the top shelf and the middle shelf. It can be also seen in Figure 5 that the use of the large wave fins, plate and zigzag fins provided more uniform drying on all the shelves compared to the use of a small wave fin.

Figure 6 shows that the decreasing of the mass of material in the drying process with the initial mass of 900 grams/rack. The biggest material mass reduction occurred on the bottom shelf because the bottom shelf of the rack firstly received the hot air. Furthermore, decline of the masses of material on the top and middle shelf were almost the same except in testing with the big wave fins which was the decreasing of the mass of material on the middle shelf is greater than the top shelf. It can be also seen in Figure 6 that uneven drying was happened. Drying rate on the bottom shelf was much greater than on the middle shelf and the top shelf.

![Figure 5](image1.png)  ![Figure 6](image2.png)

**Figure 6.** Decreasing of the mass of material on each shelf with initial mass of 900 g/rack using various types of fins (a) Small Wave (b) Big Wave (c) Plate (d) Zigzag.
Figure 7. The influence of the type of fin to decrease water content with initial masses (a) 500 g/rack, (b) 900 g/rack.

Figure 7 shows that the testing of the initial mass of 500 grams/rack (Figure 7.a) had a decreasing of water content of materials that was greater than the test with initial mass of 900 grams/rack (Figure 7.b). It can be also seen in Figure 7 that the big decreasing of water content happened in the use of the large wave, zigzag, plate and small waves fins.

Figure 8. The influence of the types of fin on the drying rate with initial masses (a) 500 g/rack, (b) 900 g/rack.

The drying rate of material in the testing with the initial mass of 900 grams/rack shown in Figure 8.b was greater than the drying rate of material in the testing with initial mass of 500 grams/rack as shown in Figure 8.a. It can be also seen in Figure 8 that the biggest drying rate of material generated by the use of large wave fin even though its value is almost equal to the use of zigzag fin. Furthermore, the use of the small wave fins had the lowest drying rate of material.

Figure 9. The influence of the types of fin on the efficiency with initial masses (a) 500 g/rack, (b) 900 g/rack.

Testing with the initial mass of 900 grams / rack shown in Figure 9.b obtained greater efficiency of testing compared to the testing with the initial mass of 500 grams / rack shown in Figure 9.a. The use of a large wave fin had the greatest efficiency even though its value was almost equal to the use of zigzag fin as shown in Figure 9 while the use plate fins produced greater efficiency compared to the use of small wave fins.

4. Conclusions
Based on the reduction in moisture content, result of the testing with the initial mass of 500 grams/rack was better than testing with initial mass of 900 grams/rack. Based on the drying rate and efficiency of
solar dryers, result of the testing with the initial mass of 900 grams/rack was better than testing with initial mass of 500 grams/rack.

The use of a large wave fins provides moisture reduction, the rate of drying and the greatest efficiency although its performance was similar to the use of the zigzag fin. The use of small wave fins has the lowest performance while the plate fins was slightly better than the use of small wave fins.

5. References
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