Design and performance test of solar vertical dryer
For Salted fish

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Abstract. Solar energy are freely available as renewable energy and characterized with pollution free and abundant source. Generally, fishermen in Aceh and other coastal areas utilized solar energy for drying their fish products in an open spaces and direct sunlight. A major problem arose in this conventional sun drying is the a high loss of dried products due to infestations by birds, rats, cats, dogs and insects. Therefore, it is necessary to design and develop a solar dryer used for fish drying in order to increase quality and quantity of fish products. In this study, solar vertical dryer was designed, developed and tested. The dimension of dryer are 240 cm height, 90 cm length and 90 cm width respectively, with co added of solar collector. The solar vertical dryer was tested for drying of salted fish when maximum solar radiation reach 603.8 W/m². The average solar radiation was 408.0 W/m², while average temperature for tray 1 to 5, and ambient are observed as 46.7°C, 43.0°C, 41.8°C, 41.3°C and 40.0°C respectively. It is also observed that relative humidity is very low inside drying chamber and as a consequence, drying rate is higher and can absorbs moisture content of salted fish rapidly and effectively.

1. Introduction
In many coastal areas, resources in fisheries sector is essential for livelihood of the community and has the potential to increase domestic economy. Indonesia has a huge source of fisheries both in terms of quantity and diversity. Moreover, industry in fisheries sectors have a remarkable link with other sectors. Further, fishing industry has a high comparative advantage in national sector as reflected from the potential of existing resources [1].

Fish is a common foodstuffs consumed by many people due to its taste, appearances and high nutritional value. Apart from its taste, fish are preferred because they provide health benefits for the developing human body. Fish has high protein content and a lower fat content compared to other animal protein sources. However, fish rot quickly due to bacteria and enzyme once revealed in an open air without preservation process. Common fish preservation process usually carried out by salting, drying, baking, smoking, cooling and even freezing [2].

Solar energy is one of the most important renewable alternative energy that can be used for various purposes to replace energy produced by petroleum [3]. The most common utilization of solar energy is to dry food and agricultural products including the fish products. Optimally, solar energy can be collected using a solar radiation energy device that reaches the earth’s surface and converts it into useful heat energy. This device is commonly called a solar collector. The solar collector is device used to collect and acquire incoming solar energy, convert into thermal energy by transforming wavelength radiation, stored as friendly thermal energy [4].

Conventional drying method employed in most of the developing countries for drying agricultural products in an open space [5]. Direct sun drying is used to denote the exposure of a commodity to direct solar radiation with the support of natural air as convective heat transfer. Conventional sun drying offers a cheap method of drying but often results to inferior quality of products due to its dependence of weather conditions and vulnerably to the attack of dust, dirties, rains, insects, pests, and microorganisms [6]. people, from rural Aceh, are using open sun drying method to dry their agricultural products as like as fishermen in Aceh also use its method to dry salted fish.
The preservation process, carried out by fishermen in the Patek area, is by conventional sun drying after cleaning and salting those fishes. It is performed for approximately three days while weather is sunny and turning the fish 4 to 5 times to uniformly distributed. This conventional drying requires a large open space area because dried fish cannot be stacked when dried. When the outside air is too dry and hot, drying can occur too fast resulting in case hardening (hardened fish meat surface). [7] Another problem is the hygiene of the dried fish is very low since the drying process is carried out in an open area which allows it to catch dust and flies.

The drying process in principle is a process of reducing the water content in fish. To prevent bacteria and harmful enzymes in fish, temperature and RH in fish storage needed to be controlled. Some important variables in the fish drying process are: temperature, RH and flow rate and drying time. Fish water content varies between 50% and 80%. To reduce bacterial and enzyme activities, moisture content of fish should be kept below 25% [8].

Solar drying has many advantages. pollution free, abundant and renewable. Open air natural sun drying of fishes is practiced in many coastal areas around the world, especially in tropical countries. Common major problems arose in conventional sun drying is high losses of dried products due to infestations by birds, rates, cats, dogs and insects. Thus, a considerable loss (30-40%) is occurred. These factors cause lot of losses to fishermen due to low quality of fish products [9], [10].

2. Methodology

2.1 climate data collection
A natural indirect type convection solar dryer was fabricated and installed at Patek, Aceh Jaya district. Longitude 95.02° E; Latitude: 04, 22° N. Patek has a tropical climate (dry and wet seasons). Solar radiation over the year on horizontal surface in Patek is found 648, 74 W/m² and maximum of 1589 W/m², minimum 38, 50 W/m². This study is performed in Patek area where large fish auction is located.

2.2 Design and construction
A vertical solar dryer was designed, developed and tested at Patek. It is suitable to be used for drying salted fish products. This dryer works based on the greenhouse effect principles by means of solar energy sources. The main frame is made of hollow iron and the walls and roof covers are made of acrylic as presented in Figure 1.

2.3 Solar collector
Solar collector is designed with 16 cm height, 86 cm length and 81.5 cm width. it consisted of transparent cover, absorber plate, heat exchanger and insulation. The transparent cover is 5 mm thick acrylic cover. The absorber plate is 2 mm thick aluminium zinc painted in black. The collector had variable angles that could be changed according to the change of the sun’s angle during the day. It is required to collect higher amount of radiation pass through solar collector.

2.4 The drying chamber
The drying chamber consists of 10 rack sections arranged vertically. This dryer has a height reaching 240 cm, length 90 cm, width 90 cm. The shape of the dryer consists of 10 drying trays which aim to accommodate the material to be dried. Each side is coated with acrylic (5 mm thick). The acrylic was fitted to the rectangular frame with sponge rubber and screwed. On the roof there is an air vent (Exhaust ventilator) which functions to circulate air and release water vapor from the material. This dryer is made closed on each side to avoid contamination of dust and gravel. At the very bottom of the device there is a solar collector that functions to collect solar radiation and convert it as heat energy which will be channel into the drying chamber. The main energy source of this dryer is solar energy. Each tray was made from wooden frame and plastic net with squared dimensions of 87 cm x 87 cm.
2.5 Experimental procedure
Further experiments were conducted to study the drying characteristics of salted fish. The research procedures carried out are as follows: splitting the fish from the back to the stomach but not breaking so that it will form two sides, then clean the tuna by removing gills and contents in the fish's stomach, then washing the fish thoroughly. The pieces of fish are weighed and dried in a drying rack. Research using this dryer was carried out for 3 days lasting from 09:00 to 17:00 pm. Data is collected every 60 minutes on measurements of temperature, humidity, wind speed and sunlight intensity. Whereas the testing of water content of the material is carried out twice a day at 12:00 and 17:00 pm.

Figure 1. Solar Vertical Dryer

3. Result and discussion
3.1 Solar radiation, Air Temperature and Relative Humidity
Solar radiation for a typical day during the solar drying of fish are shown in figure 2. During the day time (sun-shine hours), solar radiation was used to heat up the air in the collector as well as heated the circulated air in the collector and chamber. The highest solar radiation is in 180 minutes of drying process (12.00 pm). In afternoon, after 16:00 pm (in 420 minutes), the intensity of solar radiation began to decrease.

Figure 2. Solar radiation during experiment
During the experiment, variation in solar irradiance shown in Figure 2 and temperature of air at the trays inside the drying chamber after loading shown in Figure 3. Maximum solar radiation of 603.8 W/m² was noticed at 12.00 pm. The average solar radiation obtained was 408.0 W/m².

![Figure 3](image3.png)

**Figure 3** Temperature per tray of vertical solar dryer vs. ambient

![Figure 4](image4.png)

**Figure 4** Solar vertical dryer vs ambient temperature

From figure 3, the temperature at tray 1 is highest than others. The temperature is reduced when air goes through different trays in an upward direction. Drying chamber temperature reach the lowest on the upper tray 5. Therefore, the chamber temperature is reduced from tray 1 to 5. Average temperature for tray 1, tray 2, tray 3, tray 4, tray 5 and ambient are observed as 46.7°C, 43.0°C, 41.8°C, 41.3°C and 40.0°C respectively. However, Ambient temperature is still the lowest than chamber temperature (Figure 4). Its mean that the use of solar vertical dryer can increase the drying temperature of salted fish drying process compared to ambient temperature.
As shown in figure above, it describes the comparation of relative humidity between solar vertical dryer and ambient condition. It is observed that relative humidity is very low in the dryer which is important for higher drying rate as low humid air have more ability to absorb more moisture. It means that solar vertical dryer can dry salted fish in shorter duration than natural open drying. The average relative humidity of the atmospheric air and of inside chamber is found to be 83.2% and 48.6%.

4. Conclusion
Based on obtained results, we may conclude that solar vertical dryer was working effectively to dry salted fish products in Patek coastal areas. Performance tested for drying salted fish reached maximum solar radiation of 603.8 W/m2. The average solar radiation was 408.0 W/m2, while average temperature for tray 1 to 5, and ambient are observed as 46.7°C, 43.0°C, 41.8 °C, 41.3 °C and 40 °C respectively. It is also observed that relative humidity is very low inside drying chamber and as a consequence, drying rate is higher and can absorbs moisture content of salted fish rapidly and effectively.

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