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Design and Performance of Hybrid Solar Fish Dryer with Back Up Element Heater

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***Keywords*— Design, Fish Dryer, Hybrid, Solar Dryer**

***Abstract*— The aim of this research was to design and construct of hybrid solar fish dryer with back up element heater . This research was conducted in the fishing area of Ciparage Jaya, Karawang Regency, West Java Indonesia. The results of the design of the dryer has dimensions of length 120 cm, width 90 cm and height 180 cm. The main part of the dryer are collector and drying chamber which consist of 4 shelves and combined by heater elements as back up heat energy. The manufacturing cost required to design this dryer until it is ready for use is Rp. 4.453.000,- .To reduce the moisture content of 20 kg of fish to 30% with this dryer it takes 7 hours with details of 4 hours using hybrid and 3 hours using solar energy maximized by a collector. The results of statistical analysis showed that 27.5% of chamber temperature was influenced by solar radiation which is maximized by the solar collector. While the rest is influenced by the other factors such as heat source of heater element and axial fan to accelerate the flow rate of hot air. The amount of heat energy needed to reduce the water content of 20 kg of fish untill 30% using this dryer is 18,112.79 kJ.*

I. INTRODUCTION

One of the food commodities which is a high source of animal protein is fish. Fish supplies approximately 6% of the total protein requirement and 16% of the total animal protein (Jain, 2006) . Fresh fish has a water content of up to 70% in the body, so fish are very easily damaged with a relatively short shelf life (Bala & Mondol, 2001) . If post-harvest fish are not processed directly into finished products, the fish will quickly undergo a process of decay and this will cause losses. So that fast, precise and correct handling is needed to maintain the quality of fish before being marketed to consumers, it is necessary to have preservation. The processing and preservation of fish is an effort to improve the quality of storage and durability of post-harvest fishery products. The purpose of processing and preserving fish in principle is to overcome excess production while maintaining the quality of fish before being marketed or consumed, increasing the selling value of fish and extending the shelf life of fish (Imbir *et al* ., 2015) .

Some common fish preservation processes are cooling, smoking, salting, drying and curing (Handoyo & Kristianto, 2003) . Fish drying is one of the most widely used efforts to preserve fish by coastal communities. Theoretically, drying is a process of evaporation of the water content of a product until it reaches an equilibrium moisture content. The evaporated water is free water on the surface of the product and bound water in the product. Drying can also be interpreted as the process of transferring or removing the water content of the material until it reaches a certain content so that the speed of material damage can be slowed down. The process of evaporation of water requires energy. With the increase in energy in the product drying container, evaporation occurs which is followed by an increase in the water content in the drying air. In principle, the drying process is influenced by the speed of the drying air flow, the drying air temperature and the humidity (Himawanto & Nadjib, 2015)

Drying fish technique is a method to remove or remove some of the water content contained in the fish body with the help of heat energy so as to close the opportunity for bacteria or microbes to live and develop so that the shelf life of fish is longer (BERHIMPON *et al* ., 1990) . To prevent bacteria and enzymes from working in the fish's body, in addition to reducing the water content in fish, it is also necessary to control temperature, RH and air flow rate and drying time. There are four kinds of drying techniques, namely drying openly with direct sunlight, drying by burning with fuel or firewood, drying with electricity and drying with solar power in a closed manner (Tiwari *et al* ., 2016).

Most of the business actors of capture fisheries and processing of catches in Indonesia are fishermen and small-scale fisheries business actors. Generally the fishermen and coastal communities do conventional drying of fish by utilizing direct and open sunlight as the salted fish processors in salted fish in the coastal area of Ciparage Jaya, Karawang Regency, West Java . They still dry fish conventionally, namely by placing fish products on woven bamboo to dry in direct sunlight. The drying process takes about three days if the weather is sunny and by turning the fish 4-5 times so that the drying can be evenly distributed. When the outside air is too dry and hot, drying can occur too quickly, resulting in case hardening. During the rainy season, salted fish production in the coastal salted fish processing area of Ciparage Jaya decreases drastically. On the other hand, the production cost of making salted fish has almost doubled compared to the dry season because the drying process is quite long and requires more labor because the processors only depend on unpredictable weather.

In addition, in conventional fish drying activities there are several other weaknesses, including unhygienic dried fish products, weight loss of fish products produced by being eaten by insects or other animals, drying temperature cannot be regulated and drying time cannot be predicted, the amount of solar energy cannot be fix predicted(Star *et al* ., 2013) . Therefore, it is necessary to innovate fish drying technology to improve the quality and quantity of dried fish products.

Several attempts to increase the effectiveness of solar energy-based drying of fishery and agricultural products have been carried out through several previous studies aimed at improving traditional drying systems. Among them are drying products in an indirect way that only uses a dryer with solar power or uses a combination of energy from other power sources. Research by EkadewiA.Handoyo , et al .,(2012) design and testing system dryer fish powerful Sun From the results of the study, it took 6 hours to reduce the water content of fish from 60% to 38%.

Research by Thamrin , et al ,. (2011), namely the use of a rack-type solar dryer to dry cassava, this dryer consists of five shelves with a wooden frame and a transparent cover. The results showed that efficiency tools 61.47% for lower sweet potato water content wood from 38% to 14%. There is a significant difference in drying rate on each drying rack, this is due to uneven convection in the drying chamber. Hanafi Risman , et al ,. (2017) investigated the drying of anchovies using a rack-type hybrid solar energy dryer. This drying uses solar energy combined with a biomass heat source. The results showed that the drying efficiency value of the hybrid dryer was 0.695%. The small value of drying efficiency is due to the heat energy lost due to the absence of an insulator in the solar collector and the closing door in the drying chamber is not tight.

Referring to the problems mentioned above, the author will design a hybrid type fish dryer that is powered by a combination of solar energy heating element . The main power of this dryer is solar energy, the utilization of which will be maximized by using a solar collector and source power hot from heating element.

II. RESEARCH AND METHODS

The method used in this study consisted of several stages, including designing a fish dryer and testing the performance of the dryer. The activity of designing a dryer uses experiments and then proceeds with trial and learn, so in this research the design and manufacture of dryers and experiments of dryers will then evaluate and repair the equipment whether it is in accordance with the objectives to be achieved or not.

Tools and materials

The tools used in this research are tools available in the workshop such as grinding machine, electric drill, welding machine, screwdrivers, saw, pliers, elbow rulers, rivet plier, calipers and roll meters. The measuring instrument used to collect the data during performance test such as stopwatch,
analog scale, luxmeter and pyranometer. While the materials needed in this research are angled iron, zinc, clear glass, wooden blocks, plywood, waring, silicone, salted fish, rivet nails, screws, welding wire.

Design

Before making a tool design, a sketch of the dryer model is needed. The dryer design model in this study was made using the Google SketchUp 8 application as shown in fig.1

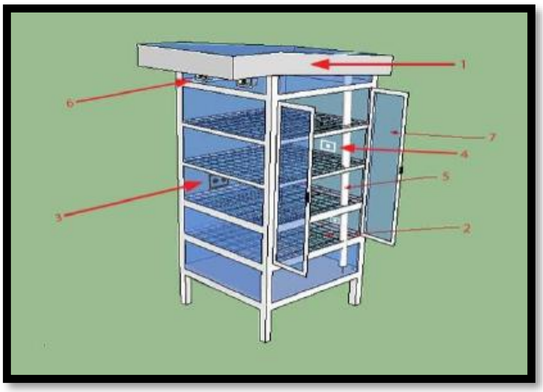

Fig 1. Design of a hybrid solar-heating element fish dryer

Description :

1. Solar collector
2. Drying chamber
3. Axial fan
4. Element heater
5. Inlet Pipe
6. Outlet
7. Dryer windows

Fish Dryer Functional Design

This dryer consists of several main components, namely:

1. Solar collector

Solar collector with dimensions of 120 x 90 cm which consists of three main components, namely absorber plate, transparent cover glass, collector frame and insulator. The collector framework uses steel slotted angle and wooden beams. The solar collector functions as a collector of solar heat converted into hot air then blowed to the drying chamber. The working principle of a solar collector is that the absorber (zinc) plate receives and absorbs solar radiation energy that falls to its surface and converts it into heat energy so that it flows in the collector above the absorber plate. Heat transfer in the air collector will occur by conduction, convection and radiation. The transparant cover uses ordinary clear lime glass with a thickness of 5 mm placed above the absorber. According to M Burhan Wijaya (2007) that the most effective glass thickness for transparent covers on solar collectors is 5 mm, while the distance between the glass and the effective absorber plate is 30 mm.

2. Drying chamber

The drying chamber is the main part of the drying house consists of a drying rack to put fish products to be dried. The drying chamber consists of four drying racks which are arranged vertically. The drying rack is made of RK type fish waring material with a hollow steel frame. The dimensions of each shelf are 120 x 90 cm. The use of fish waring is intended to prevent fish products from sticking to the shelves, besides that the hot air in the drying chamber is evenly distributed on each shelf.

3. Blower (Axial Fan)

Axial fan serves to circulate heat from the collector to the drying chamber. The number of fans is two with a power of 12 watts each which is driven by electric power, on this fan a thermostat is installed to control the collector temperature, if the collector temperature is below 37ºC then the fan will turn off.

4. heating element

As a back up source of heat energy, this fish dryer uses two heater elements that are driven by an electrical energy source. These two elements are mounted vertically on the second and fourth shelves. The heater element is also installed with a thermostat to control the temperature in the drying room to match the desired temperature. The maximum temperature of the drying chamber is set at 50ºC. According to Abdullah (2003) the temperature of the drying chamber should not exceed 50˚C because it will cause case hardening.

5. Inlet Pipe

The inlet pipe is a supporting component in the dryer which functions to channel hot air from the collector to the drying rack. The inlet pipe uses a 2 inch PVC pipe that is connected to an acrylic box where the axial fan is. The addition of this component refers to previous studies which with several existing designs resulted in temperature differences and uneven heat distribution in the drying chamber. So with the addition of this component it is possible to maximize the distribution of hot air to spread to all drying racks.

6. Control System

The control system on this fish dryer adopts the automation system used in hatching chicken eggs, namely the use of a thermostat. A thermostat is a device that functions as a temperature controller to maintain the ideal temperature according to a predetermined target value. The type of thermostat that will be used is a digital thermostat. One thermostat is placed on the surface of the collector and is connected to the axial fan and the second thermostat is placed in the drying room connected to the heater element. The way it works is that the thermostat will cut off the electricity that drives the axial fan if the collector temperature reaches the minimum limit. This is to avoid that the rate of air flowing from the collector is only hot air, if the temperature of the collector reaches the lowest temperature limit, only cold air will flow into the drying chamber. Then the way the thermostat works which is connected to the heater element is that the thermostat will cut off the flow of electricity from the heater element if the temperature of the drying room has reached the maximum temperature limit.

I. RESULT AND DISCUSSION

The results of the design of a hybrid solar dryer back-up heater element is the result of the design obtained from the collection of literature and the design deficiencies of the dryer in previous studies. In this design, several components and basic changes to the existing dryer design will be added. After the design is made, the process of making a fish dryer is carried out starting from the manufacture of collectors, dryer housing frames, drying racks, hot air ducts, back up heaters as well as manufacture and installation of axial fans and houses. The design results of this fish dryer has dimensions *(l x w x h)* 120 x 90 x 180 cm

Fig.2 Results of the design of the fish dryer

Testing of the fish dryer was carried out for 3 days from 15 to 17 June 2022. The drying trial process was carried out for 7 hours every day from 08.00 to 15.00 WIB. The parameter measured is the temperature in the drying chamber and above the collector measured using a digital thermohygrometer HTC-2 with a temperature tolerance level of 1% and a humidity tolerance of 5%. The temperature in the drying chamber is regulated using the STC-1000 thermostat with tolerance of 1ºC. The temperature of the drying room is set in the range of 35ºC – 50ºC, meaning that when the temperature of the drying room reaches the minimum limit (35ºC), the heater will automatically turn on and when it reaches the maximum temperature (50ºC), the heater will automatically turn off.

Solar Radiaton Intensity

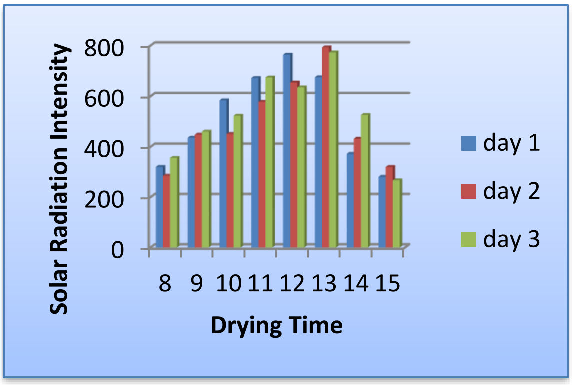

Fig 3. Drying time and solar radiation

Based on the graph in fig.3, it can be seen that during the testing process the intensity of solar radiation tends to increase from 08.00 to 12.00 am and decreases after 13.00 pm. This shows that during the process of testing the weather in the Ciparage Jaya area, Karawang Regency tends to be stable.

Moisture Content

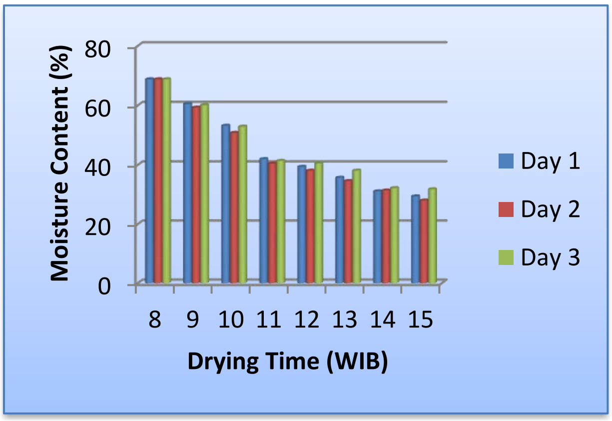

Fig 4. Comparison of drying time and mouisture content

Based on the graph in Fig.4 above, after testing for three repetitions there was a relatively constant decrease in water content. The maximum decrease in water content occurred on the second day of repetition, reaching 28% wb after being dried in a dryer for seven hours. While the repetition on the 3rd day showed that the final water content only reached 31.8% but this value still met the water content value recommended by SNI, which was less than 40%.

Descriptive Analysis

The results of hybrid dryer testing that the data obtained are drying room temperature, collector temperature, solar radiation intensity and water content of dried fish. The variables of drying room temperature and solar radiation intensity will be analyzed and tested using a simple linear regression model statistical analysis using a tool, namely IBM statistic SPSS 24, to find out how much influence of the collector has by comparing the solar radiation intensity with the temperature of the drying room. Determination of simple linear regression method because there is one independent variable and one dependent variable.

Table 1. Analysis of Dryer Room Room Temperature and Solar Radiation Intensity

Day	Time (WIB)	Dryer Room Temp (ºC)	Solar Radiation Intensity (W/m ^{2})	Collector Temp (ºC)
Day 1	08.00	36.8	320	31.2
	09.00	38.2	436	33.0
	10.00	43.5	584	37.9
	11.00	48.1	672	38.2
	12.00	51.4	764	40.5
	13.00	50.2	675	43.7
	14.00	48.7	372	38.1
	15.00	47.6	281	37.5
Day 2	08.00	37.2	285	32.3
	09.00	39.8	448	36.7
	10.00	44.2	451	37.1
	11.00	47.1	578	39.4
	12.00	49.4	654	42.4
	13.00	52.3	793	40.3
	14.00	50.5	432	37.2
	15.00	49.1	320	38.9
Day 3	08.00	35.5	356	31.7
	09.00	37.2	460	35.0
	10.00	44.9	523	36.6
	11.00	48.1	674	39.1
	12.00	51.4	635	38.6
	13.00	50.3	773	40.3
	14.00	48.8	526	36.4
	15.00	50.1	267	37.1

The test was carried out three times with the same type and weight of fish and in wet conditions, the test data can be seen in the table above. The temperature data on the collector is influenced by the level of sunlight intensity at that time and is recorded hourly for 8 hours. So the drying chamber temperature will depend on the collector temperature. In the statistical analysis that will be used is a simple linear regression statistical analysis where to find out how much influence the collector has by comparing the level of sunlight intensity with the temperature of the drying room.

Table 2.Variables Entered

Variables Entered/Removed [a]			
Model	Variables Entered	Variables Removed	Method
1	Solar radiaton[b]	.	Enter
a. Dependent Variable:dryer room temperature			
b. All requested variables entered.			

The table above describes the variables entered and the methods used. In this case, the variables included are the sun intensity variable as the independent variable and room temperature is the dependent variable and the method used is the enter method.

Table 3. Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,524 [a]	,275	,242	4.73106
a. Predictors: (Constant), solar intensity				

The model summary table above can be seen that the amount of correlation value (R) is 0.524, it means between the sunlight radiation intensites variable and the drying room temperature variable has the correlation with the correlation value is 0.524. For the test output, the coefficient of determination (R square) is 0.275 which means that the influence of the independent variable (sunlight intensity) on the dependent variable (drying room temperature) is 27.5% and the rest is

Table 4. ANOVA

ANOVA[a]						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	186,875	1	186,875	8,349	,009[b]
	Residual	492,425	22	22,383		
	Total	679,300	23			
a. Dependent Variable: drying room temperature						
b. Predictors: (Constant), solar intensity						

Anova table above can be seen that the calculated F value = 8.349 with a significance level value of 0.009 <0.05, then the regression model can be used to predict the drying room temperature variable or in other words there is an influence of the sunlight intensity variable (x) and chamber temperature dryer (y).

Tabel 5. Coefficients

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standard Coefficients Beta	T	Sig.
1	(Constant)	37,104	3,177		11,678	,000
	Solar radiation	,017	,006	,524	2,889	,009

a. Dependent Variable: dryer room temperature

The table above is the result of the T test or also known as the partial test, it is used to test how the influence of each independent variable individually on the dependent variable. In the coefficients table above, it can be seen that the constant (a) value is 37.104 while the sunlight intensity value (regression coefficient) is 0.017, so the regression equation can be written:

Y= a + bX

Y= 37.104 + 0.017X

The equation can be explained:

1. The constant of 37.104 means that the consistent value of the drying room temperature variable is 37.104
2. The regression coefficient X of 0.017 states that for every 1% addition of the value of the intensity of sunlight, the value of the drying room temperature increases by 0.017. The regression coefficient is positive, so it can be said that the direction of the influence of the variable X on Y is positive.

The basis for decision making in a simple linear regression test:

1. Based on the significance value of the coefficients table, a significance value of 0.009 < 0.05 was obtained, so it can be concluded that the sunlight intensity variable (X) has an effect on the drying room temperature variable (Y).
2. Based on the t value : it is known that the calculated t value is 2.889 > 2.074 . so it can be concluded that the variable of sunlight intensity (X) has an effect on the variable temperature of the drying room Y

Heat Calculation Analysis

To calculate the total calorific value needed for the evaporation of water content in the fish's body, first it is calculated based on the following data:

Initial weight of fish = 20 kg

Drying chamber temperature = 45.8 C

Initial moisture content (K_{aib}) = 68% = 0.68

Drying time = 7 hours

Specific heat of water ($Cp\ air$) = 4.2 kJ = 1.01 kcal/kg

Air temperature (Tu) = 35.8 C

1. Mass of water in fish (M_1)

$M1 = W_b . M_{ib}$,where:

W_b = moisture content of wet fish (68%)

M_{ib}= Mass of wet fish (20kg)

M1 = 68% . 20 kg = 13.6 kg

- Heat to heat water (Q_{k1})

$Q_{k1} = M_1 . C_{Pairs} . (Tp – Tu)$, where:

M1 = 13.6 kg

C_{Pair} = 1.01 kcal/kg°C

Tp = T drying chamber (45.8 C)

Tu = T air (35.8 C)

Qk1 = 13.6 kg. 1.01 kcal/kg°C. (45.8 – 35.8)°C = 137.36 kcal = 574.71 kJ

2. Evaporated water mass

M_2 = (Wb – Wk) × Mib ,where :

Wk = Moisture content of dry fish (30%)

Mib = Mass of wet fish (20 kg)

M_2 = (68 – 30)% × 20 kg = 7.6 kg

- Heat to evaporate water (Q_{k2})

$Q_{k2} = m2 . L_{water}$, where:

M2 = $_{7.6}$ kg

L_{water} = 540 kcal/kg°C

Qk2 = $_{7.6}$ kg . 540 kcal/kg°C = 4,140 kcal = 17321.76 kJ

Fish meat mass (M_3)

$M_3 = (100\% – W_b) \times M_{ib}$, where:

W_b = Moisture content of wet fish (68%)

M_{ib}= Mass of wet fish (20 kg)

M_3 = (100 – 68) % × 20 kg = 6.4 kg

- Heat to raise the temperature of fish (Q_{k3})

$Q_{k3} = M_3 . C_{Pikan} . (T_p – T_u)$, where:

M3 = 6.4kg

C_{Pikan} = 3.387 kJ/kg C

T_p = T drying chamber (45.8 C)

T_u = T air (35.8 C)

Q_{k3} = 6.4 kg. 3.387 kJ/kg C.(37 - 33) C = 216.32 kJ

So the total heat needed to evaporate the moisture content of 20 kg of fish in this drying chamber is:

$Q_k = Q_{k1} + Q_{k2} + Q_{k3}$

= (574.71 + 17321.76 + 216.32) kJ

= 18,112.79 k

III. CONCLUSION

Based on the results of the study, it was shown that a hybrid solar fish dryer with solar back up heater element is highly recommended to be applied by salted fish processors because the manufacturing cost of making the tool is very affordable, which is only Rp. 4,453,000, - The dryer test results show that to reduce the water content of 20 kg of fish from 70% to 30% with this dryer, it takes only 7 hours, with details of 4 hours using hybrid power and 3 hours using solar power.

The results of statistical analysis show that 27.5% of the temperature produced by the drying chamber is influenced by solar radiation which is maximized by the solar collector, while the rest is influenced by other factors including the heat source of the heater element and axial fan to accelerate the hot air flow rate. The amount of heat needed to reduce the water content of 20 kg of fish using this dryer is 18,112,79 kJ.

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