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PERFORMANCE TEST OF SOLAR CABINET DRYER AND SOLAR TUNNEL DRYER ON DRYING COCOA BEANS

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Abstract

The process of drying under direct sunlight has many obstacles that must be faced such as using a large area of land as a place for drying, unpredictable weather such as rain and strong winds, and direct contact with the environment such as animals and dust. Traditional way such as cacao drying under the sun will reduce the quality and quality of the cocoa beans caused by the constraints faced, among others: large land factors, erratic weather factors and environmental factors.This study aims to compare dryers for cocoa beans. The comparison carried out is a comparison of tools, moisture content, mass, quality of beans, and the time required by each tool in drying. The drying tools used are traditional solar cabinet dryers and solar tunnel dryers. Conventional drying uses direct sun contact on cocoa beans, and solar tunnel dryer uses two types to dry cocoa beans: hot air absorbed by solar collectors and direct sun. In contrast, solar cabinet dryer uses hot air absorbed by solar collectors and driven by fans in the drying room. The research was carried out from 09.00 until 16.00 in 31/2 hours, so in a day, there are three observation data for each research tool. To the research results, the time required for each tool is different, the solar cabinet dryer tool takes four days, and the solar tunnel dryer traditionally takes three days to dry cocoa beans; drying is done 7 hours a day. The highest ambient temperature is up to 36.3oC, the temperature entering the drying chamber for the solar cabinet dryer is up to 54.2oC, and the solar tunnel dryer is up to 51oC. With a mass of 1.5 kg of material dried to 0.50 kilograms, leaving a moisture content of 12%.

Keywords: solar cabinet dryer, solar tunnel dryer

1. INTRODUCTION

Agriculture in Indonesia is one of the keys to the economy of the Indonesian people. Some Indonesians work as cocoa farmers (Theobroma cacao L). Cocoa crop development efforts are still directed at increasing the population (land area) and the production and quality of yields. Cocoa is one plantation crop that continues to receive attention to be developed [1][2].

Indonesia is one of the countries that produce cocoa. In the world, Indonesia became the third largest cocoa producer in the 1980s. Indonesia's cocoa production tends to increase from year to year. According to the latest data obtained from FAO, Indonesia's cocoa amount was 659,776 tons in 2017. However, the amount of cocoa bean production in 2017 decreased compared to 2014. If in 2014 Indonesia was able to produce around 728,400, in the following years, the amount of Indonesian cocoa production fell even further [3][4]

In one of the regions of North Sumatra province, in West Nias regency, some people work as cocoa farmers. Every year, cocoa bean production in West Nias Regency does not increase, with an average annual production of under 500 tons. This data can be seen from 2011 to 2017. The harvested cocoa beans are traditionally dried. The traditional way of drying cocoa beans is by drying them in direct sunlight. This method is usually done by placing cocoa beans that have undergone fermentation (fermentation is an activity carried out to remove pulp) on the media used for drying. The medium used is usually a tent, sack, or terrace with a cement base on the zinc roof of a house. The process of drying under direct sunlight has many obstacles, such as using a large area of land as a drying place, uncertain weather, such as rain and strong winds, and direct contact with the environment, such as animals and dust. Traditional sun drying will reduce the quality of cocoa beans due to the constraints faced, such as the use of large areas of land for drying, erratic weather, and environmental factors [5], [6]

A solar tunnel dryer is a solar energy dryer used to optimize the use of sunlight in the drying process. This solar energy dryer is handy for drying agricultural products. Drying using a solar tunnel dryer does not use a large land area and is not in direct contact with environmental disturbances. UKRIM's Renewable Energy Laboratory has solar cabinet dryers and solar tunnel dryers.

Solar tunnel dryers and solar cabinet dryers are very efficient in improving the quality of drying cocoa beans. In contrast, the solar cabinet dryer uses two components: solar collectors and drying rooms. Solar collectors function to absorb heat from solar rays and then flow it into the drying room in the form of hot air. In the drying room, the drying process occurs. The hot air will absorb the water content of the dried material, and the hot air containing water will be drained into the environment.

One alternative for this system to be efficient is to utilize the hot air coming out of the drying chamber. The hot air from the dryer has flowed back to the solar collector. The atmosphere is soaked in the drying room by the solar collector and diverted back to the solar collector. With this system, the air temperature will continue to increase to dry the material faster. However, too high a temperature is unsuitable because it can damage the dried material. For that, an automatic system is needed that can control temperature and humidity [7][8].

To support this research, we present several similar studies:

1. Performance Test of Hybrid Solar Tunnel Dryer on Cocoa Drying (Theobroma cacao Linn), Research aimed determine the total energy received by the hybrid solar tunnel dryer, and to determine the efficiency of the hybrid solar tunnel dryer. The research method was an experiment method. Date retrieve procedures include: intensity of solar radiation, the room temperature of drying, furnaces temperature and ambient temperature [9]
2. Mechanism Of Some Agricultural Dryer Machinery. The research method used is to review the workings of agricultural dryers. The way the agricultural dryer works on cocoa beans, grain, coffee and cloves has advantages and disadvantages from the drying machine [10]
3. Analysis of Drying Rate in the Cabinet Dryer . This study aims to analyze the drying rate in the manufacture of mocaf flour on a cabinet and find out the effect of the variable time and temperature of the dryer on the moisture content found in mocaf flour and the degree of smoothness produced [11].

2. LITERATURE RIVIEW

Drying Theory

Drying is a process of simultaneous transfer of heat and water vapor that requires heat energy to evaporate the water content transferred from the surface of a material dried by a normally hot drying medium.

There are several problems that are often encountered in drying process. The first is a problem related to the quality of drying products. Operations performed in drying are complicated operations that include heat and mass transfer and possibly some other processing rate, such as physical or chemical changes of a product, where hal it may cause changes in the quality of the product. Possible physical changes include droughts and clots. In addition to physical changes, there may also be chemical changes that alter the scent, color, texture, or other properties of solids.

Then the next problem is that the conditions and properties of the dried material vary considerably, It sometimes requires modification of the traditional drying process (by drying or simply heating) into drying processes with more specific character and ability and with the needs of each product.

Traditional Drying

Dryers are traditionally known as natural drying or by drying sun. The traditional drying utilizes direct sunlight. Drying in the sun is a traditional lightening that requires no special equipment and expensive operational costs.

Sunlight drying depends heavily on the weather, temperature, and humidity around the drying area. In addition, lightening with sunlight also takes a long time and the dried material is less maintained. The drying process of the dryers will be constrained during the rainy season. The obstacle will be a hindrance to the drying process of cocoa beans.

Solar *Cabinet Dryer*

Solar collectors are the central device in thermal solar systems that collect and absorb sunlight radiation. Sunlight hits the absorber on the solar collector, and some of the light will be reflected in the environment while most of it will be absorbed. The heat energy is transferred to the fluid circulating inside the solar collector to be utilized in various applications that require heat. Heat is collected in a solar collector to increase the ambient temperature and blown into the material to be dried. To dry an agricultural product, a considerable amount of energy is needed. Most farmers do their drying in the hot sun. The ambient temperature is around 33˚ C, while the drying temperature for agricultural commodities is around 60-70˚C. It takes longer to dry a product if we use heating air at ambient temperature or lower than the drying temperature. [8][7](Arta, 2014). The shape of the solar collector can be seen in Figure 1

Figure 1. Solar Collector.

Solar *Tunnel Dryer*

Solar tunnel dryer is a way of drying by utilizing solar energy using a collector as a heat absorber that makes maximum use of solar energy. The solar drying system consists of the main parts: the solar collector and the drying room. The solar collector is a device that can absorb solar radiation to heat the air in the collector room. The heat in the solar collector room can be used for drying. Absorption of solar radiation requires special equipment, namely flat plate collectors and concentrator collectors. Collectors are divided into fluid collectors (water and oil) and air collectors. To make the drying time relatively short and the quality of the drying results better.

The drying process aims to reduce the water content contained in the dried material, reduce the water activity in the material, and inhibit the artifices of microbes in it to increase the durability, quality, and quality of drying. By using a solar dryer, the absorbed heat will accumulate in the dryer, thus accelerating the drying process of the material [12][13].

Figure 2. Drying using a solar tunnel dryer

a. ATMega8 microcontroller

The AVR ATmega8 is an 8-bit CMOS microcontroller with AVRRISC architecture that has 8K bytes of In-System Programmable Flash. This low-power consumption microcontroller can execute instructions with a maximum speed of 16MIPS at a frequency of 16MHz. Compared to the ATmega8L, the difference lies only in the voltage required to work. For the ATmega8 type L [14], this microcontroller can work with a voltage between 2.7 - 5.5 V, while for the ATmega8, it can only work with a voltage between 4.5 - 5.5 V.

b. ATMega8 Pin Configuration

The ATMega8 pin configuration can be seen in Figure 4.

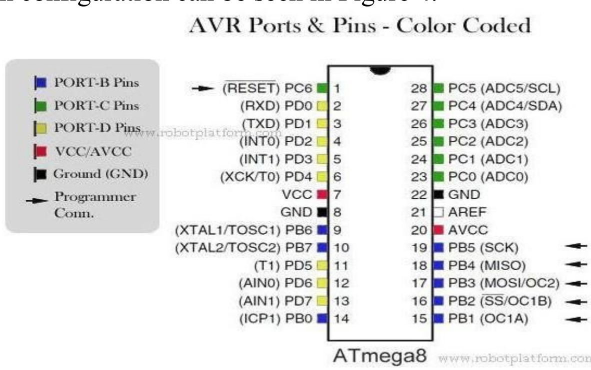

Figure 3. ATMega8 Pin Configuration.

ATMega8 has 28 pins, each of which has a different function, both as a port and other parts. The following will explain the process of each ATMega foot.

c. Arduino Uno

Arduino Uno is a microcontroller-based board on ATmega328 which has 14 digital input/output pins (of which six pins can be used as PWM outputs), six analogue inputs, 16 MHz crystal oscillator, a USB connection, a voltage source connector, an ICSP header, and a reset button. The Arduino Uno contains everything needed to support a microcontroller. Connecting it to a computer via USB or providing DC voltage from a battery or AC to a DC adapter can already use it. The shape of the Arduino Uno can be seen in Figure 5.

The Arduino Uno uses an ATmega16u2 programmed as a USB to- serial converter to communicate with a computer via a USB port.

d. Communication System of Arduino Uno

The Arduino Uno has several facilities for communicating with computers, Arduinos, and other microcontrollers. The Atmega328 provides serial UART TTL (5V) communication, which is available on digital pins 0 (Rx) and 1 (Tx). An Atmega 16U2 onboard channels its serial communication via USB and appears as a virtual com port for software on a computer. The Arduino firmware uses the standard USB COM driver; no external drivers are required. However, on Windows, an inf file is needed. The Arduino software includes a serial monitor that allows simple data to be sent to the Arduino board. The Rx and Tx LEDs on the board will blink when data is sent via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1). The Atmega328 also supports I2C and SPI communication [15][16].

e. Arduino *Development Environment*

The Arduino Development Environment consists of a text editor for writing code, a message area, a console, a toolbar with buttons for standard functions, and several menus. The Arduino

Development Environment connects to the Arduino board to upload programs and also communicate with the Arduino board.

f. Temperature and Humidity Sensor (DHT22)

DHT 22 is a temperature sensor and air humidity sensor module with a temperature measurement range between -40-80 ° C and an air humidity measurement range of 0-100% RH. This sensor module has a temperature measurement accuracy of about 0.5 ° C and a humidity measurement accuracy of 2% RH. Figure 8. DHT22 Temperature and Humidity Sensor.

This sensor has digital signal calibration that can provide temperature and humidity information. This sensor is classified as a component with an outstanding level of stability and includes a temperature-measuring resistive element (NTC). Besides having excellent quality, fast response, and affordable prices. The DHT 22 also features a very accurate calibration. This calibration coefficient is stored in the memory program so that the module reads the sensor coefficient when the internal sensor detects something. This module is suitable for many temperature and humidity measurement applications [17].

Cocoa Bean

Cocoa plants, or cacao (*Theobroma cacao L*), is an agricultural community that contributes to increasing State revenues in supporting national development and the socio-economic life of the people. The main problem of cocoa in Indonesia is the low quality and productivity of several things, including poor planting materials, less than optimal cultivation technology and pest and disease attacks. Cocoa cultivated by the people is generally not appropriately fermented, so the quality produced is not under federal standards [18].

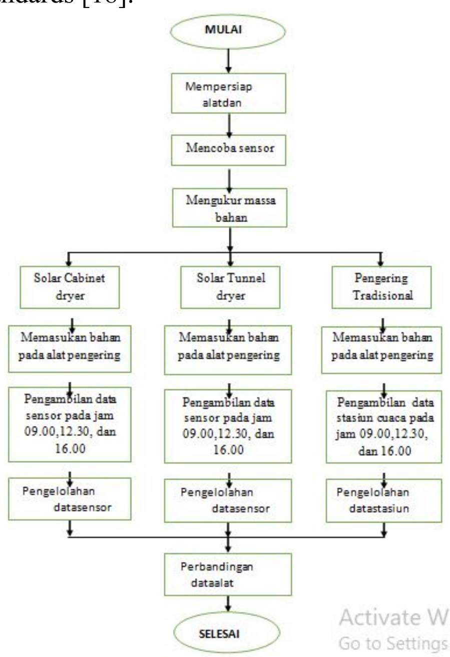

Figure 4. Research Chart

3. METHOD

The experiment was done in comparison between traditional drying and renewable energy drying which using solar cabinet dryers and solar tunnel dryers to search for faster drying processes.

Traditional drying is a research where the research material receives direct sunlight, and is in direct contact with the environment, dust, winds, and even eaten by animals. Traditional drying has used solar radiation as the only source of energy in the process of fermentation. Renewable energy is using solar cabinet dryers as dryer that uses hot air absorbed by collectors. The solar cabinet dryer has a separate drying chamber with a solar collector connected by a pipe, hot air absorbed by the collector thrust by a fan going through the connecting pipe to the dryer. The fan that drives hot air is moved, usually using solar panels, PLN and 12v batteries. While drying which using a solar tunnel dryer is a dryer that using two sources of energy in the process of drying, a table-shaped solar tunnel dryer that has a roof, and is covered with transparent plastic and a solar collector room.

4. RESULT AND DISCUSSION

Solar Cabinet Dryer Research Tool Performance

A solar cabinet dryer is a tool made of aluminium, zinc and other building materials. This tool is in the form of a rectangular box, where the packet contains aluminium zinc that has been rolled up and painted black. Inside, the box is coated with styrofoam which holds the air produced by the collector, with a box cover using transparent glass. Both ends of the box are perforated as a fan and connecting pipe to the drying room. Inside the drying room, there are several shelves and air holes to exit the drying room.

This tool works because the fan pushes the hot air produced by the collector into the drying room. The hot air made by the fan passes through the connecting pipe to enter the drying room, the air that enters the drying room passes through the object or material being dried, and the air exits through the pipe hole for air discharged into the environment.

(a) Solar dryer

(b) Cabinet dryer solar collector.

(c) Drying chamber.

(d) Drying rack

(e) Connecting pipe to the drying chamber

Figure 5. the pipe hole for air discharged into the environment

Measurement Results

The measurement results carried out at the UKRIM renewable energy laboratory have the following data.

Table 1. Research results using a solar cabinet dryer from November 12 to 15, 2020

Tanggal > Jam	T_ling (◦C)	H_ling (%)	T_in (◦C)	H_in (%)	T_out (◦C)	H_out (%)	Massa bahan (kg)	Radiasi (w/m²)	Massa air	Massa kering	Kadar Air (%)
12/11/2020 > 09:00	29	70	37.3	61.3	36.8	55.7	1.5	551	1.01	0.50	67%
12/11/2020 > 12:30	33	59	47.1	46	48.1	37.2	1.4	883	0.91	0.50	65%
12/11/2020 > 16:00	30.6	67	34.8	65.5	33.3	66.2	1.3	186.4	0.81	0.50	62%
13/11/2020 > 09:00	31.6	64	45.5	43.9	45.1	40.9	1.4	595	0.91	0.50	65%
13/11/2020 > 12:30	33.5	61	48.8	41.9	48.5	34.5	0.88	840	0.39	0.50	44%
13/11/2020 > 16:00	36.2	72	36.4	70.5	34.9	69.9	0.82	208	0.33	0.50	40%
14/11/2020 > 09:00	36.3	75	40.3	90.5	40.7	62.3	0.82	568	0.33	0.50	40%
14/11/2020 > 12:30	35.3	47	51	31.9	51.1	28	0.7	830	0.21	0.50	29%
14/11/2020 > 16:00	29.9	68	32.5	92.4	32.1	72.5	0.64	551	0.15	0.50	23%
15/11/2020 > 09:00	30.2	66	45.2	43	45	39.3	0.64	568	0.15	0.50	23%
15/11/2020 > 12:30	35.2	46	54.2	27.9	51.2	29.5	0.56	830	0.07	0.50	12%
12/11/2020 > 12:30	33	59	47.1	46	48.1	37.2	1.4	883	0.91	0.50	65%

The temperature rises from 10:00 to 15:00 if the weather is good or not cloudy; when the temperature increases, the humidity drops, and vice versa. In Table 1, it can be seen that the solar cabinet dryer has the highest temperature (T_ling) at 12:30 a.m., which is 35◦c and the lowest humidity (rH_ling), which is 46% on the third day of drying; the temperature and moisture depend on the weather at the time of the research. At the same time, the highest temperature and lowest humidity entering the drying chamber (T_in) were 54.2 oC (rH_in), or 27.9%, on the fourth day of drying. The highest temperature and lowest humidity exiting the drying chamber (T_out) were 51.2 oC (rH_out) and 29.5% on the fourth drying day, respectively. The most increased solar radiation at 12:30 p.m. was 883 W/m2. While the mass reduction from 09:00 to 12:30 is 0.52kg, in the humidity column, the difference between the numbers from (rH_in) and (rH_out) is a large number of different numbers, all because of the poor sensor used. The mass of kako beans at the beginning of drying was 1.5 kg with a moisture content of 67% after experiencing the drying process for four days and seven hours per day, from a mass of 1.5 kg to 0.50 kg with a range of 12%. Because of the cocoa drying standard in this study, the cocoa group must reach 0.50 kilograms.

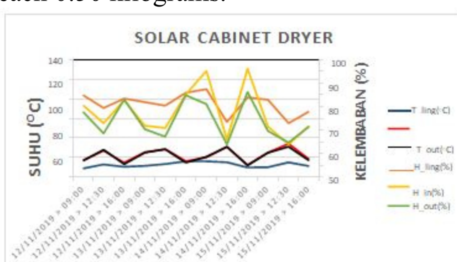

Figure 6. Temperature and Humidity of Solar Cabinet Dryer

The numbers are similar in each study. Graph 1 on the graph is known on the first day and the second day the highest number at 09.00 with environmental humidity and low rh_out; at 16.00 environmental humidity, rh_in, and rh_out, the graph is almost the same. While on the third day, the moisture at 09.00 and 16.00rh-in has the highest number, and on the last day, the highest number of environmental humidity, temperature from the first day to the temperature of the previous day.

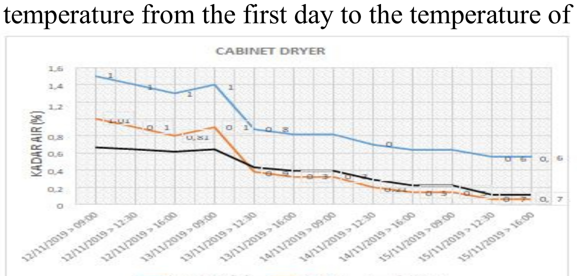

Figure 7. Comparison of Moisture Content, Mass of Water and Mass of material (kg) Solar Cabinet Dryer

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Figure 7 shows a decrease in cocoa mass, where the initial group of 1.5kg at 09.00 becomes 1.3kg in the afternoon, or on the first day, the abundance of cocoa beans has decreased by 0.2kg with a moisture content of 62%. On the second day, the mass of cocoa increased by 1.4 kilograms because the cocoa beans were moist; after drying the second day, the abundance of cocoa beans dropped to 0.88kg with 40% moisture content; the third day, the mass of cocoa was 0.7kg, with 23% moisture content, on the last day the group of cocoa reached the research drying standard with an abundance of 0.56 with 12% moisture content. And the mass of water in the material decreased following the decrease in a lot of cocoa beans. The average mass loss per day after drying is 0.23kg per day with seven hours of drying.

Solar Tunnel Dryer

Table 2. Research results using a solar tunnel dryer from November 12 to 15, 2020

Tanggal > Jam	T_ling (◦C)	H_ling (%)	T_in (◦C)	H_in (%)	T_out (◦C)	H_out (%)	Massa bahan (kg)	Radiasi (w/m²)	Massa air	Massa kering	Kadar Air (%)
12/11/2020 > 09:00	29	70	35.8	56.7	38.1	61.8	1.5	551	1.01	0.50	67%
12/11/2020 > 12:30	33	59	46.2	34.9	52.3	45.3	1.3	883	0.81	0.50	62%
12/11/2020 > 16:00	30.6	67	35.2	54.3	34.9	68.7	0.78	186.4	0.29	0.50	37%
13/11/2020 > 09:00	31.6	64	45.8	53.3	46.6	37.4	0.8	595	0.31	0.50	38%
13/11/2020 > 12:30	33.5	61	44.6	49.8	50.3	26.4	0.64	840	0.15	0.50	23%
13/11/2020 > 16:00	36.2	72	37.5	66.2	38.8	49.1	0.62	208	0.13	0.50	20%
14/11/2020 > 09:00	36.3	75	42.7	64.7	47.7	37.1	0.62	568	0.13	0.50	20%
14/11/2020 > 12:30	35.3	47	51.9	39.8	58.6	19.2	0.52	830	0.03	0.50	5%
14/11/2020 > 16:00	29.9	68	31.9	77.8	32.4	60.8	0.52	551	0.03	0.50	5%

The temperature rises from 10:00 to 15:00 if the weather is good or not cloudy; when the temperature increases, the humidity drops and vice versa. In Table 2, it can be seen that the solar tunnel dryer has the highest temperature (T_ling) at 12:30, which is 35◦c and has the lowest humidity (rH_ling), which is 46% on the third day of drying; the temperature and moisture depend on the weather at the time of the research. At the same time, the highest temperature and lowest humidity entering the drying chamber (T_in) was 46.2oC (rH_in) 34.9% on the first drying day. The highest temperature and lowest humidity exiting the drying chamber (T_out) was 58.6oC (rH_out) 19.2% on the third drying day. The most increased solar radiation at 12:30 pm was 883 W/m2. While the most mass reduction at 09:00 to 12:30 is 0.52kg, in the humidity column, the difference from the numbers from (rH_in) and (rH_out), there is a significant distance of numbers that are different due to the poor sensor used. The mass of kako beans at the beginning of drying is 1.5 kg with a moisture content of 67% after experiencing the drying process for four days and seven hours per day, from a mass of 1.5 kg to 0.50 kg with a range of 12%. Because of the cocoa drying standard in this study, the abundance of cocoa must reach 0.50 kilograms.

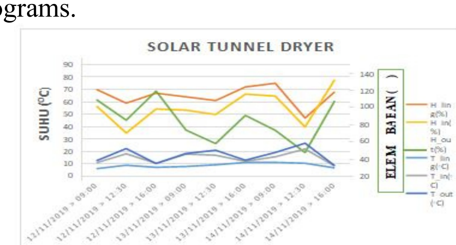


Figure 8. Temperature and Humidity of Solar Tunnel Dryer

Figure 8 shows the temperature and humidity; the top graph is the humidity graph, and the bottom is the temperature. Humidity in rh_ling, rh_in, and rh_out on the first day of the study at 09.00

rh_ling was very high than rh_in, and rh_out, at 16.00 rh_out, rose its graph through rh_ling. On the second day of the survey, rh_out dropped significantly while the distance from rh_ling and rh_in was close, and on the third day, rh_in rose its graph at 16.00, passing the rh_ling chart. The temperature of rh_out and rh_in is very close at 09.00, and on the first day at 16.00, the humidity of rh_in and rh_out is the same. And so is the second at 09.00, and on the third day, the temperature of T_out the graph rises while T_ling the value of each study does not increase.

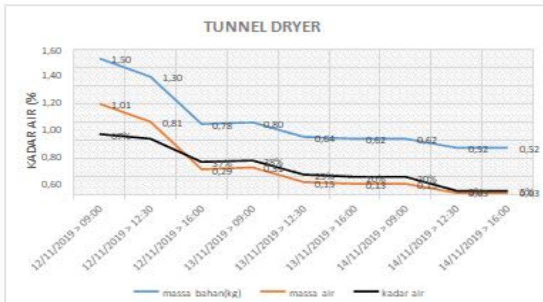


Figure 9 Comparison of Moisture Content, Mass of Water and Mass of material (kg) Solar Tunnel Dryer

Figure 9 of this graph is about the mass of the material and the abundance of water contained in the material; at the beginning of the study, the group of the material was 1.5kg with a water mass of 1.01 and a moisture content of 67%, drying on the first day dropped to an abundance of material of 0.78kg with a water mass of 0.20 and a moisture content of 37%, on the second day dropped from a group of 0.78 to 0.62kg with a water mass of 0.13 and a moisture content of 20%. And the third day or the last day of drying, the abundance of material is 0.52kg with a water mass of 0.03 and a moisture content of 5%; it can be interpreted that the average mass loss per day after drying is 0.33kg per day with seven hours of drying.

Traditional

Table 3 Research results using traditional drying from November 12 to 15

Tanggal > Jam	T_{ling} (°C)	H_{ling} (%)	Massa bahan (kg)	Radiasi (w/m²)	Massa air	Massa kering	Kadar Air (%)
12/11/2020 > 09:00	29	70	1.5	551	1.01	0.50	67%
12/11/2020 > 12:30	33	59	1.1	883	0.74	0.36	55%
12/11/2020 > 16:00	30.6	67	0.76	186.4	0.51	0.25	35%
13/11/2020 > 09:00	31.6	64	0.74	595	0.50	0.24	33%
13/11/2020 > 12:30	33.5	61	0.58	840	0.39	0.19	15%
13/11/2020 > 16:00	36.2	72	0.56	208	0.38	0.18	12%
14/11/2020 > 09:00	36.3	75	0.56	568	0.38	0.18	12%
14/11/2020 > 12:30	35.3	47	0.54	830	0.36	0.18	8%
14/11/2020 > 16:00	29.9	68	0.54	551	0.36	0.18	8%

Table 3 shows the results of traditional drying, where the conventional dryer takes three days to dry the cocoa beans. In the drying process, the highest ambient temperature on day three was up to 36oc, with 75% humidity, with a mass of 0.56kg. And the lowest ambient temperature was up to 29oc, with 70% humidity on the first day of the study. The mass change of cocoa beans after drying was highest on the first day from 12:30 to 16:00 with a value of 0.34kg, and on the second day, the mass change was only slightly below the first day with a weight of 0.18kg, and the third day dropped to 0.2kg. The mass change in cocoa beans after drying is not far from the solar radiation at the drying time, and on the first day of drying, the highest radiation reached 883w/m2 at 12:30 am.

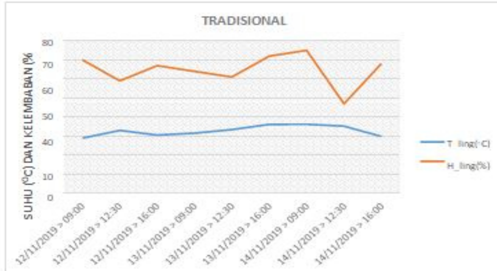


Figure 10. Environmental Temperature and Humidity

Figure 10 in this graph shows temperature and humidity; the top graph is the humidity graph, and the bottom chart is the temperature. Humidity in rh_ling on the first day of the study at 09:00 rh_ling at 12:30 fell, and the temperature rose; at 16:00, the humidity rose, and the temperature fell. On the second day, it dropped and rose from 12.30 to 16.00, and on the third day, the humidity was very low at 12.30 and again rose to 16.00. Humidity is very dependent on temperature. The ambient temperature was different from the first to the last drying day.

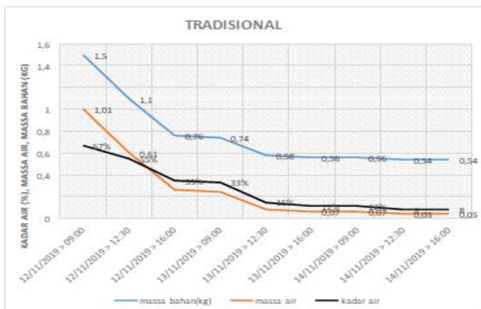


Figure 11. Environmental Temperature and Humidity

In this Figure 11 at the beginning of the study, the mass of material was 1.5kg with a water mass of 1.01 and a moisture content of 67%. Drying on the first day dropped to an abundance of material of 0.76kg with a water mass of 0.61 and a moisture content of 55%, on the second day dropped from a group of 0.74kg to 0.56kg with a water mass of 0.07 and a moisture content of 12%. And the third day or the last day of drying, the abundance of material is 0.54kg with a water mass of 0.05 and a moisture content of 8%. It can be assumed that the average mass loss per day after drying is 0.32kg per day with seven hours of drying.

Solar Radiation

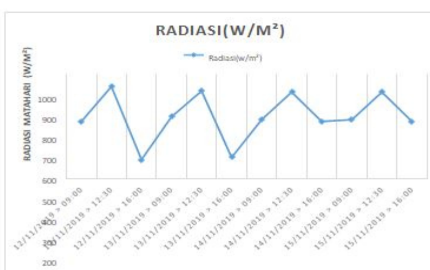
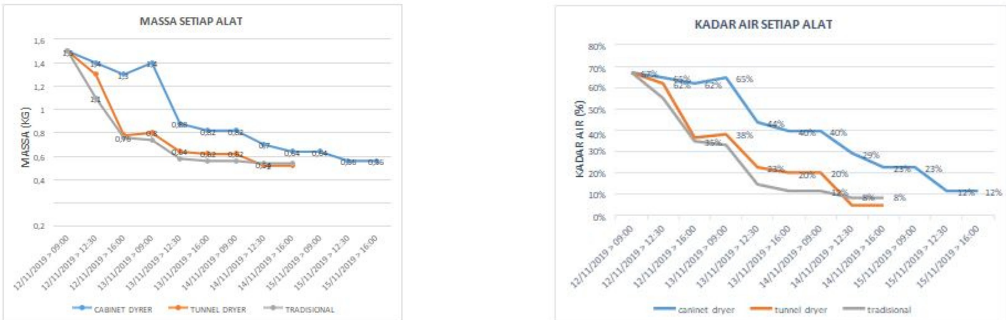


Figure 12 Solar Radiation

Figure 12 can be seen in the solar radiation graph on the first day at 09.00, around 551 w/m2, rising to 883 w/m2 at 12.30, and falling again to 186.4 w/m2 due to cloudy weather at the time of data collection. The second and third days are still stable up and down radiation values; only on the first day does the radiation reach a number below 200 w/m2 at 16.00.

Comparison

From the research that has been done, there is a comparison of the mass, moisture content and quality of each research tool that has been used in this study.

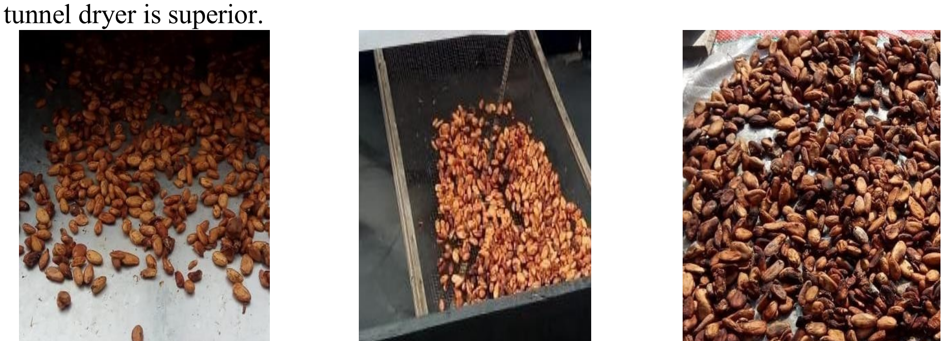


(a) (b)

Figure 13 (a) Mass comparison of each research tool, (b) Comparison of moisture content of each research tool

Figures 13(a) and (b) graph the comparison between the three drying devices. It can be seen in the graphs that solar tunnel drying and traditional drying both require three days of drying, while solar cabinet drying requires four days of drying time. The mass of cocoa beans on the first day of drying from the initial group of 1.5kg decreased by 0.76kg for traditional and 0.78 kilograms for solar tunnel dryer, so it has a difference of 0.2kg drying on the first day. And 1.3kg for solar cabinet dryers, the difference is very far in value from both traditional tools and solar tunnel dryers. On the second day, the mass of material dropped by 0.56kg for the conventional and 0.62 kilograms for the solar tunnel dryer, so it had a drying difference of 0.06kg on the second day. And 0.88 kilograms of the solar cabinet dryer. On the third day of the study, the mass of the material dropped to reach the standard set in the cocoa bean drying study, 0.54kg for traditional with 8% moisture content and 0.52kg with 5% moisture content for solar tunnel dryer, so it has a drying difference of 0.2kg on day three. And 0.64kg for the solar cabinet dryer, and 0.56 on day four, with a moisture content of 12%, the above explanation of the comparison between the time and mass of each research tool and the length of time required by each research tool.

The graph shows that traditional drying is faster in cocoa beans, but judging from the final mass and moisture content, the mass of material dried from solar tunnel dryer drying is 0.52 kg with 5% moisture content. While traditional drying is 0.54kg with 8% moisture content, it is evident that the solar tunnel dryer is superior.



(a) (b) (c)

Figure 14. (a) quality of solar cabinet dryer, (b) quality of solar tunnel dryer, (c) quality of traditional dryers.

In terms of quality and colour, the rate of traditional drying has a dark brown colour resembling black, with the surface of the seeds looking rough, and the roots are not filled, maybe dirt or dust attached that is carried by the wind when drying. In contrast, the quality of the solar tunnel dryer has a light brown colour with a smooth and clean surface and filled seeds. Because it uses a solar tunnel dryer, the tool is made like a table and roofed. The roof is covered with transparent plastic so that sunlight enters and is protected from dust and dirt carried by the wind so that the material does not have direct contact with nature. And the quality of the dryer using a solar cabinet dryer is the same quality and colour as a solar tunnel dryer. The solar tunnel dryer is superior to the traditional solar cabinet dryer. Both in quality and the final mass of drying and moisture content.

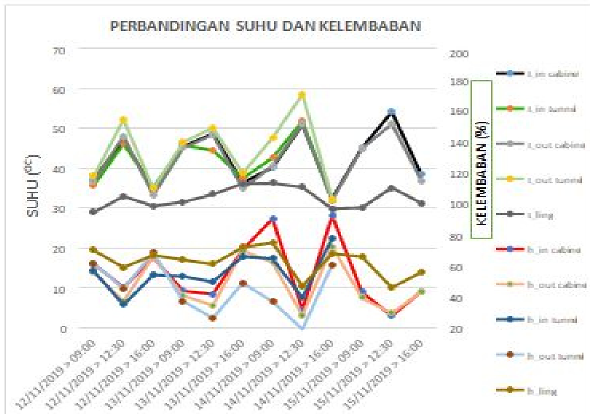


Figure 15. Comparison of Temperature and Humidity of each of the 3 dryers

Figure 15 on the graph each comparison of temperature and humidity between the two research tools, the solar tunnel dryer and solar cabinet dryer. On the t_out tunnel, the dryer is higher than the t_out cabinet because the t_in tunnel dryer is a more significant value than the value of the cabinet dryer. While the humidity of h_in cabinet with h_in tunnel is higher than h_in cabinet dryer, and the moisture of h_out tunnel on the first day at 09.00 until 12.30, the graph is the same as h_out, but after 12.30 on the first day, it changes. As seen in Graph 4.8, graph h_out cabinet dryer has a higher value than the h_out tunnel dryer.

5. CONCLUSION

The length of time required by each dryer is: for solar tunnel dryer and traditionally drying for three days with different moisture content and mass of the final material, in the solar tunnel dryer with an absolute abundance of 0.52kg with 5% moisture content, and for traditional tools with a final mass of 0.54kg with 8% moisture content. Meanwhile, the solar cabinet dryer dries for four days with an absolute abundance of 0.56kg with a moisture content of 12%. Regarding quality and colour, cocoa beans dried by solar tunnel dryer have a clean surface with light brown colour. While the quality of traditionally dried beans is dark brown-black, and the surface of the beans is rough and slightly wrinkled. And the quality and colour dried by the solar cabinet dryer are almost the same as those dried by a solar tunnel dryer; the only difference is the drying time. It can be concluded that of the three drying tools used in drying cocoa beans, drying using SOLAR TUNNEL DRYER is better than drying traditionally and using a solar cabinet dryer.

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