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Electric Energy Grain Dryer with Aluminum Foil Coated Dryer Walls

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***Abstract* - Solar powered grain drying machines (PGTM) have advantages over fossil energy, namely they are cheap and simple. However, the main obstacle is the dependence on time and weather. To overcome these weaknesses, it is necessary to create a combined system, namely, a solar and PGTL electric drying system. This machine works during the day and continues at night using electric power. This will speed up the grain drying process without having to wait for the sun to rise. The method of supplying electrical power in the drying room is carried out directly with incandescent lamps installed on the drying racks. The amount of electrical power provided to the lamp is equivalent to the average solar energy during the day that enters the drying room, which is 400 Watts. The drying room used for research has an area of 0.9 x 1 meter and a height of 1.7 meters and is equipped with 5 shelves for placing the grain. The hot air flow in the drying room is used by a blower at 2 speeds, namely 4, 7 and 10 m/sec. The walls of the drying room are covered with aluminum foil to increase the efficiency of lamp heat absorption that can be received by the grain. The performance of an electric grain dryer (PGTL) is expressed in terms of drying efficiency or reduction in water content in the grain (Mw) and machine efficiency, η_{pgel}. The test was carried out at night for 5 hours with a total amount of grain of 8 kg divided into 4 shelves of 2 kg each. From the test results of the PGTL machine, it was found that the reduction in water content in grain (Mw) at air speeds of 4 m/s, 7 m/s and 10 m/s, respectively, was 7.45%, 7.9%, 9.45%, and machine efficiency respectively 20.1, 21.1% and 25.45%.**

Keywords: Rice Dryer, Grain moisture content, Efficiency, Aluminum foil.

I. INTRODUCTION

The potential for solar energy in Indonesia is around 4.8 KWh/m^2 or the equivalent of 112,000 GWp. However, solar energy has not been utilized optimally; only around 10 MWp has been utilized [1]. Utilization of the potential of solar energy in the agricultural sector, for example in the process of drying rice grain, is still limited. There is still a lot of drying of rice grain after harvest which is done traditionally, namely drying under the direct heat of the sun. This drying method takes quite a long time, 2-3 days, and there is a decrease in the quality of the grain, which can cause the rice grain to be mixed with dust or dirt [2-3].

The aim of drying rice grain is to reduce the water content in the grain after harvest from 24% to 12-14%, so that the rate of grain damage due to biological and chemical activity slows down [4]. To achieve the desired drying level, a drying device is needed, one of which is a solar powered rice grain dryer (PGTM). When compared with electrical energy and fuel grain dryers, the main advantages of PGTM dryers are cost-effective, simple and environmentally friendly [5-6]. Meanwhile, the main advantage of electric energy and fuel dryers is that the engine is more compact and drying quantity is greater, the disadvantages are equipment and energy consumption which is expensive and not environmentally friendly

The working principle of a solar powered grain dryer (PGTM) is to collect solar heat energy into a heat collector made from a black plate (absorber). With the help of a blower, outside air is passed over the surface of the absorber plate to pick up heat and pass it to the grain drying chamber. So this tool has 2 core components, namely a heat collector and a drying chamber. This tool is used as a grain dryer during the day, while it does not operate at night [7]. To improve the performance of PGTM, modifications were made to this tool, namely a solar & electric grain dryer (PGTL). This grain dryer modification is intended so that the machine can work in various conditions, bright sun, cloudy or at night. This dryer is equipped with an electric heater in the form of 4 incandescent lamps of 100 watts each, which are installed on each shelf [8].

The results of the PGTL engine test which was carried out only at night with electrical energy (heating lamp), obtained the highest engine efficiency of 22.85% at an air speed of 10 m/s. Because this drying room consists of glass walls and light can still radiate out, the efficiency of heating and drying grain in the drying room is not optimal. In further testing, the research team made additional modifications,

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namely the walls of the drying chamber were coated with aluminum foil (PGTL-Mk1), to increase the heat absorption of the lamp into the dried grain, which is expected to increase drying efficiency.

The parameters that influence this test are speed, temperature, air humidity and drying time [9]. The test was carried out with three variations, namely 4, 7 and 10 m/second, while the energy input came from 4 lamps with a total load of 400 watts. To determine the effect of adding aluminum foil to the walls, the test results were compared with previous PGTL tests.

II. RESEARCH OBJECT

2.1 Performance of Solar and Electric Grain Dryer (PGTL)

PGTL performance is expressed in 2 parameters [4], namely drying efficiency or expressed in the reduction of grain moisture content (Mw) and drying machine efficiency (η_{pgel}). The decrease in grain water content is expressed from the mass of water in the grain that is evaporated during the drying process (Mw). This is expressed as the difference between initial grain mass (Mi) and final grain mass (Mf).

$$Mw = Mi - Mf$$

The reduction in water content or drying efficiency can be expressed in percent, namely the mass of water in the grain that is evaporated divided by the initial mass of the grain,MIn

$$Mw = (Mw/Mi)x100\ \%$$

The second performance is engine efficiency, η_{pgel} which is expressed as the percentage of heat of vaporization of water (Q_{in}) in grain to energy input (P_{light}).

$$\eta_{pgel} = (MIn.Hfg/Plight\ )x\ 100\%$$

Where Hfg is the latent heat of vaporization of water.

2.2 Description of Solar and Electric Grain Dryer (PGTL)

The PGTL dryer consists of two main components, namely a solar air heater (PUTM) and a drying chamber (Figure 1). The PUTM air heater is an air duct on the base of which a black plate is installed as an absorber (heat collector) of solar energy and is covered with clear glass with a thickness of 5 mm. PUTM has walls made of wood which have length, width and height of 0.5 x 1 x 0 .15 m.

The incoming air is channeled by a blower which is installed on the inlet side of the PUTM. This air flows past the hot surface of the black plate (heat collector), thereby increasing the temperature of the PUTM exit air. This hot air is passed into the drying room to dry the grain.

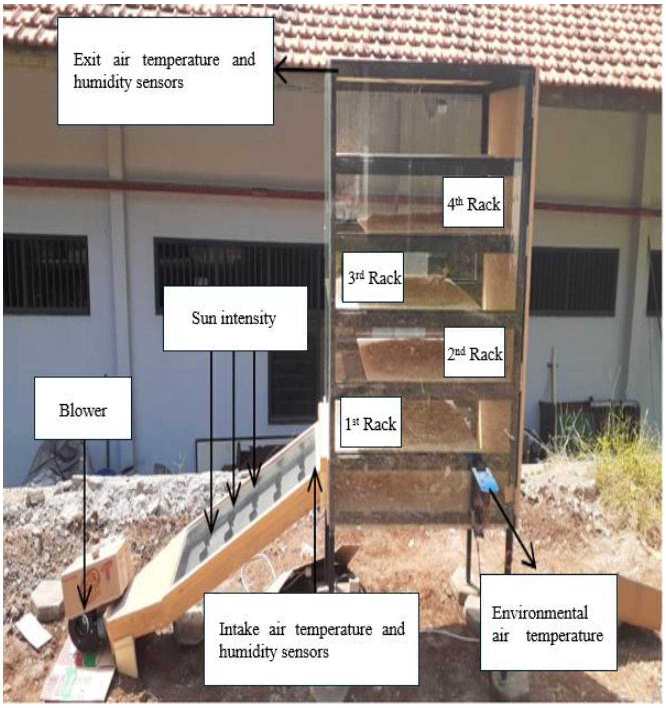

Figure 1: Solar and Electric Drying Machine (PGTL)

The cupboard/drying room is made from an iron frame with glass walls measuring 1 x 0.95 x 1.70 m. In drying chamber installed and drying rack made of wooden planks which functions as a place for grain to be dried. Above these shelves, 4 incandescent lamps of 100 watts each are installed which are used when solar energy is low due to rain or cloudy conditions and at night. So PGTL can be operated during the day and at night. This test is a continuation of our testing [7], namely testing grain using solar energy (PGTM) and testing using electrical energy which was carried out previously.

There are several modifications in this test, namely, the walls of the drying room are covered with aluminum foil to increase the heat absorption efficiency of the lamp that can be received by the grain. The drying racks were replaced with racks made from aluminum plates to increase heat transfer from the plates to the grain pile (PGTL-Mk1). The blower originally installed at the inlet of the air heater collector (PUTM) was moved to the inlet of the drying chamber (Figure 2).

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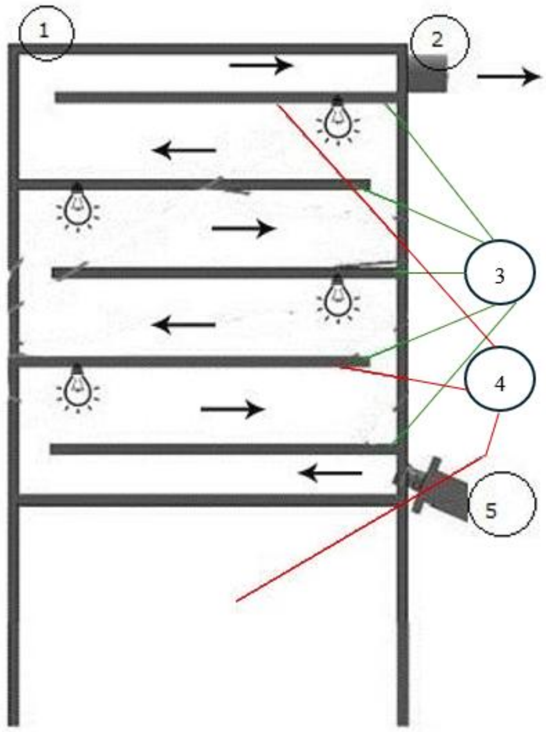
2.3 Data Collection Method



Point 1 = Drying Room
Point 2 = Air Outlet
Point 3 = Grain Rack
Point 4 = Temperature and Humidity Sensors
Point 5 = Blower and Air Intake

Figure 2: Electric drying machine (PGTL-Mk1) with aluminum foil-coated walls

The PGTL-Mk performance test was carried out for 5 hours at 19.00 – 24.00 WIB. This was a continuation of the previous PGTL test (Kamal 2021), with the modification of adding aluminum foil installed on the wall in the drying room. The data taken is the weight of grain per shelf, temperature and humidity of the air entering and leaving the drying room, as well as environmental temperature and humidity. The total weight of grain is 8000 grams which is placed on four shelves with the weight of grain per shelf being 2000 grams. To measure temperature and humidity, a data acquisition system is used, namely using a DHT22 (AM2302) sensor so that the data is recorded in Microsoft Excel which is connected via a microcontroller-Arduino Uno [10].Several measuring instruments consisting of temperature and humidity sensors, speed meters (Anemometers), solar power meters and scales are shown in Figure 3.

Tests were carried out at 3 speed variations of 4.7 and 10 m/sec. The performance of PGTL-Mk1 consists of drying efficiency or reduction of water content in grain (Mw) and drying machine efficiency (η_{pgel}). To determine the effect of using aluminum foil on engine performance, the results of this test were compared with the previous PGTL test [8]. The test results and comparison of PGTL engine performance are shown in Tables 1, 2 and 3, as well as Figures 4 and 5. A picture of the measuring tool can be seen below:

Figure 3: Measuring tools used

III. RESULTS AND DISCUSSION

3.1 Drying Efficiency and Tool efficiency

The test aims to compare the performance of our grain dryer (PGTL-Mk1) and the performance of Kamal's grain dryer (PGTL). The data taken is the air temperature entering and leaving the dryer, environmental temperature, humidity of the incoming and outgoing air and the speed of the air leaving the dryer. PGTL performance is expressed in terms of drying efficiency and tool efficiency. Drying efficiency or reduction of water content in grain, Mw. Meanwhile, tool efficiency is the tool's ability to dry grain per unit of heat from the lamp, ,η_{pgel} Testing is carried out from 18.00 to 24.00 WIB. The test results are shown in Tables 1,2 and 3 as well as Figures 4 and figure 5.

Table 1: Changes in grain water content at v = 4 m/s

Grain mass per shelf at speed v = 4 m/s which has been optimized				
Time	1st Rack	2nd Rack	3rd Rack	4th Rack
19:00	2000	2000	2000	2000
20:00	1960	1956	1948	1939
21:00	1930	1923	1919	1902
22:00	1900	1899	1886	1878
23:00	1883	1876	1869	1858
0:00	1867	1856	1845	1836
Mw	6,30%	5,90%	7,45%	8,00%
Mw Total	7,45%			

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Table 1 is the decrease in grain mass during drying which is calculated based on equation 1. From the initial grain weight (Mi) of 8000 grams for a total of 4 shelves and the weight of grain after drying (Mf) which is 7404 grams, so the reduction in water content, Mw is obtained as following:

$$\text{Mw} = \frac{(\text{Mi} - \text{Mf}) \times 100\%}{\text{Me}}$$

$$= \frac{(8000 - 7404) \times 100\%}{8000} = 7{,}45\ \%$$

It can also be seen in table 1 above that each shelf has a different decrease in water content. The total drying rate or overall reduction in grain moisture content was 7.45% for 5 hours. The efficiency of the tool is calculated based on equation 2, which is shown by the following calculation:

$$\eta_{pgel} = \left(\frac{\text{MIn.Hfg}}{\text{Plight}}\right) \times 100\ \%$$

$$= \frac{596 \times 2429087}{400 \times 18000} = 20{,}1\ \%$$

Other test data, namely at speeds of 7 and 10 m/sec, are shown in tables 2 and 3 below.

Table 2: Changes in grain water content at v = 7 m/s

Grain mass per shelf at speed v = 7 m/s which has been optimized				
Time	1st Rack	2nd Rack	3rd Rack	4th Rack
19:00	2000	2000	2000	2000
20:00	1957	1948	1930	1922
21:00	1936	1927	1910	1899
22:00	1899	1890	1889	1873
23:00	1876	1868	1860	1858
0:00	1856	1849	1842	1827
Mw	7.20%	7.55%	7.90%	8.65%
Mw Total	7,9%			

Table 3: PGTL Mk1 Grain Weight v = 10 m/s

Grain mass per shelf at speed v = 7 m/s which has been optimized				
Time	1st Rack	2nd Rack	3rd Rack	4th Rack
19:00	2000	2000	2000	2000
20:00	1921	1903	1890	1879
21:00	1884	1878	1869	1858
22:00	1865	1854	1845	1836
23:00	1840	1837	1827	1810
0:00	1822	1816	1808	1800
Mw	8.90%	9.20%	9.60%	10.00%
Mw Total	9,46%			

It can be seen in Tables 2 and 3 above that the reduction in total water content is 7.9% for a speed of 7 m/sec and 9.46% for a speed of 10 m/sec. The tool efficiency is 21.1% and 25.45%. From the data above, it is known that by increasing the drying air speed (from 4, 7 and 10 m/sec), an increase in tool efficiency is obtained, from 20% to 21.1% and 25.5%. This explains that increasing speed can increase the rate of heat and mass transfer in dried grain as evidenced by a greater decrease in water content (from 7.45, 7.9 and 9.45%).

3.2 Effect of drying chamber modification on PGTL performance

Previous tests [8] were carried out with the walls of the drying room without being covered with aluminum foil and wooden boards as a place for the grain to be dried. Then the research was developed by modifying the walls and drying boards, namely by covering the walls of the drying chamber with aluminum foil and replacing the wooden boards with aluminum plates (PGEL-Mk1). The test results can be shown in Figure 4 and Figure 5 below.

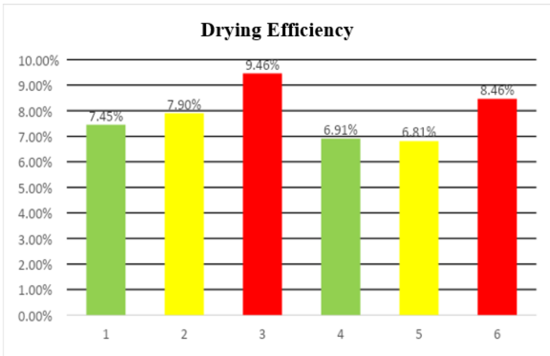

Figure 4: Comparison of Drying Efficiency obtained by PGTL- Mk1 with PGTL

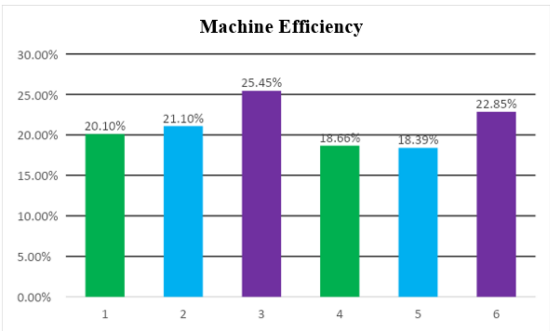

Figure 5: Comparison of machine efficiency that can be achieved by PGTL Mk1 and PGTL

Figure 4 shows a comparison of the reduction in water content or drying efficiency in PGTL and PGTL-Mk1. It can be seen that the use of aluminum foil layers on the walls and drying racks of aluminum plates increases the drying efficiency for all variations of given speed. The highest drying

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efficiency at a speed of 10 m/sec was 8.46% for testing on PGTL and increased to 9.46% for PGTL-Mk1. Likewise, in terms of the machine's ability to absorb lamp energy for drying, the machine's efficiency also increases. It can be seen from Figure 5 which shows that the highest engine efficiency occurs at a speed of 10 m/sec with a comparison of 22.8% for PGTL and 25.45% for PGTL-Mk1. The increase in drying efficiency and machine efficiency occurs because the walls of the chamber covered with aluminum foil will increase the absorption of lamp energy into the grain. This increase occurs because the heat of the lamp that hits the wall will reflect back into the grain. Meanwhile, replacing wooden shelves with aluminum plates will increase the conduction heat transfer through the bottom aluminum plate to the pile of grain on the surface of the plate above.

IV. CONCLUSION

1. Electric powered grain dryer with modification (PGTL-Mk) with blower air speed variations of 4 m/s, 7 m/s and 10 m/s produces drying efficiency of 7.45%, 7.9%, 9.45% respectively and machine efficiency of 20.1%, 21.1% and 25.45%
2. Using aluminum plates as grain racks and aluminum foil wall coverings (PGTL-Mk1), and when compared with the dryer before modification (PGTL), an increase in machine efficiency was obtained from 22.8% to 25.45% (2.65 %)
3. Increasing the speed of hot air in the drying chamber will increase the efficiency of drying which occurs at a speed of 10 m/sec.

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