Design of Grain Dryer using Pressure the Flow of Air Heat Forced Convection Method

Peter Sahupala and Reinyelda D. Latuheru

***Abstract* — The availability of such vast land so that the transfer to the agricultural sector which is large enough to be difficult to stem along with technological advances in agriculture will allow the farmers' businesses to be more enthusiastic in the hope that better growth in agricultural production will be achieved. On the other hand, it will reduce losses/loss of yields due to the production process so that there is an improvement in the application of harvesting and postharvest technology which seems to be a prospective source of production growth. In its development, local farmers in Merauke using the rice drying method still use the old method, namely drying in the hot sun in an open field. If the weather is favorable, the drying process will not take up to 14 days and sometimes if the field or yard is not enough, someone will use the services of someone else to dry it. This also raises complaints because the costs that must be incurred by farmers will be even greater. The research developed is to design a rice grain dryer where the characteristics or drying method is a dryer with hot air/gas pressure produced from the combustion process in the furnace. The objectives of this research are to design a dryer installation that can dry grain effectively, efficiently and economically with the Pressure Flow Heat Forced Convection method as an air heater in the drying room, determine the percentage of grain moisture content with free convection and forced convection with drying time, and calculate the efficiency of the dryer installation with forced convection as a hot air sucker from the combustion furnace to the drying chamber and compare the results. The research was appointed based on the problems that exist in the community, especially in the Kurik district, Wonorejo village, Merauke Regency, Papua. This research is also a manifestation of the vision of Musamus University, which is to become a reference for empowering independent communities based on local wisdom through downstream research. The results showed that for testing the weight loss of grain, the best results were obtained between the 540th and 620th minutes with a weight of less than 15 g. So from 12 tons of wet grain that was dried after a drying process for 12 hours, the amount of water that evaporated for a 3 kg sample was 0.875 kg so that the dry grain weight was 2.125 kg. Total drying of 12 tons of grain to 10.5 tons. The total evaporation of water vapor in the grain is 0.875 x 12000 kg = 10500 kg (10.5 tons). This shows that the heat used for the rice grain drying process can be used optimally where the efficiency of the grain dryer installation is 71%.**

***Keywords* — Convection, Dryer, Grain, Heat, Merauke.**

I. Introduction

One of the triggers that the quality of Merauke's local rice has not been maximized is strongly influenced by weather factors in the grain drying process. With weather conditions, manual drying of grain (drying on the road and yard) cannot be maximized. Rice in Merauke is currently abundant, but the quality needs to be improved. To overcome this problem, in addition to the 6 units of rice dryers in Merauke, even though the conditions are not optimal yet, it is necessary to look for other alternatives that can assist the drying process, of course by paying attention to the quality of the rice produced. Technological advances and research developments in order to obtain better post-harvest production yields as well as promote more promising production growth continue to be encouraged. In its development, local farmers in Merauke using the rice drying method still use the old method, namely drying in the hot sun in an open field. If the weather is favorable, the drying process will not take up to 14 days and sometimes if the field or yard is not enough, someone will use the services of someone else to dry it. This also raises complaints because the costs that must be incurred by farmers will be even greater.

The drying device that will be studied for its drying characteristics is the drying method with hot air/gas pressure produced from the combustion process in the furnace. Air from outside will be sucked in by a blower entering through the fire pipes in the furnace and then pressed into the drying chamber. By maximizing the tool, it is expected to be able to dry grain yields with a level of dryness (water content) on an even material. In addition, the use of the dryer is also expected to maximize the heat energy from the combustion furnace. The fuel used for the combustion process in the furnace is rice husk.

Some of the problems that are of concern in this study are how to install a grain dryer with a capacity of 12 tons using the Pressure Flow Heat Forced Convection method to obtain even drying results, how to determine the percentage of grain moisture content during forced convection drying, how to create a web-based information system. To control the drying chamber temperature, how to analyze the thermal efficiency of the dryer.

II. Literature Review

A. State of the Art

a. Joint Decree of the Head of the Food Security Guidance Agency No: 04/SKB/BBKP/II/2002 Harvested Dry Grain (GKP), grain containing water content greater than 18% but less than or equal to 25% (18%<KA<25 %). Stored Dry Grain (GKS) is unhulled rice that contains water content greater than 14% but less than or equal to 18% (14%<KA<18%).

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Milled Dry Grain (GKG) is grain that contains a maximum water content of 14% [1].

b. The thermal efficiency of the grain dryer is equipped with a secondary collector. The results showed that it took time for the percentage of harvested grain moisture content from 24.75% to decrease to 13.43%-13.82% dry milled grain moisture content, i.e., 3 hours-5.5 hours with efficiency 9.88%-44.96% for tools that use secondary collectors. and 4 hours-6.5 hours with an efficiency of 8.65%-33.72% on the tool without using a secondary collector [2].
c. The speed of airflow and the number of heating pipes will affect the amount of energy absorbed to evaporate the water content in the grain. The value of the energy produced by using 2 air heating pipes is 3,948,7353,979 Watt with the amount of airflow being pressed by a fan of 13 m/s, while when using 3 air heating pipes, energy is obtained 469,041,223 W with the amount of airflow pressed by the fan. fan 13 m/s. The airflow rate and the number of heating pipes used will affect the amount of heat energy needed to evaporate the moisture content in the grain [3].
d. The grain dryer has a length of 3 meters, a width of 40 centimeters, a height of 1.25 meters, a motor power of 100 W, a grain flow rate of 0.1 Lt/sec, a blade shaft rotation of 46 rpm, a transmission reduction of 1:50 rotation. Grain drying air temperature 420C Grain flow rate 0.1 Lt/s, Hot air flow rate 0.68 [4].
e. A grain dryer with the use of Diesel motor exhaust gas and calculate the efficiency of a grain dryer with heat transfer analysis. The mass velocity of the incoming exhaust gas is 36.75 kg/s with the overall heat transfer coefficient at the inlet side is 92.7334404 W/m^2 ºC. With the 2400 rpm motor rotation, the total heat transfer in the heat exchanger is obtained which is the maximum heat that can be utilized of 0.226296111 kW and the effectiveness of the heat exchanger is 60.95%. [5].
f. Rainy season by using a blower with a capacity of 19 m^3/minute with a power of 0.5 HP; outside air temperature 30 °C; drying air temperature 50-60 °C; RH: 70-90%; The initial grain moisture content is 30%, the final grain moisture content is 17%. The dryer is capable of drying 40-50 kg of grain/hour with husk consumption of 4-6 kg/hour [6].
g. The use of biomass to produce heat energy in the grain drying room obtained an average temperature of 33.8 °C and the relative humidity in the drying room of 57% obtained a drying process of 7 hours. The percentage of water content in the grain is 15.57% with the energy value obtained is 160,662.15 kJ. While the grain drying process by utilizing solar energy combined with biomass energy obtained an average temperature of 39.98 °C, relative humidity of the drying chamber on average 45.85%, drying time 7 hours, final moisture content on average 15.33% [7].
h. The development of a rice dryer without affecting weather conditions which is the development of a conventional dryer that is based on Node MCU where the machine is equipped with a programmable as well as supporting components, namely a heating element that functions to increase the temperature in the machine, temperature sensor DHT11 [8].
i. The development of a rice dryer using air heating pipes shows that all supporting components can function optimally, where to dry rice grains weighing 5 kg, after the drying process is complete, 4.9 kg of rice is obtained or about 0.1% moisture content can be evaporated [9].
j. The grain dryer is a static model, where the rice is dried according to the size of the area and is treated with 2 cycles for 1 hour for each cycle. The grain mass is fed back to the second cycle. In this second cycle drying has been achieved with the maximum water content removed is 47% [10].
k. Thermal characteristics of the dryer design in the application of appropriate technology through the use of rice husks. The test results show that the average ambient air temperature of 32.14 °C can be increased to 92.10 °C, 93.27 °C, and 94.96 ºC in the drying chamber for variations in the diameter of the furnace wall hole 8 mm, 10 mm, and 12 mm, each. Sequentially the temperature in the drying chamber reaches a maximum of 119.13 °C, 127.98 °C, and 140.89 °C [11].
l. Model of rice drying kinetics at certain drying times under drying conditions. Drying was carried out at capacities 1, 2, and 3 kg, temperature 55 °C, drying time 45 minutes, and initial moisture content of 31.23 ± 0.26% (d.b.). Measurements of temperature, relative humidity, pressure drop, and moisture content were carried out at 1, 2, 3, 4, 5, 10, 15, 25, 35, and 45 minutes. The drying data obtained were mounted on six mathematical drying kinetics models. The water content of rice was reduced to a final moisture content of 14.04 ± 0.75% (d.b.) [12].
m. The process of designing the PID controller in this application uses the Ziegler - Nichlos I method. From the calculations, the parameter values Kp = 7.45, Ki = 0.26 and Kd = 52.15. From the 50 °C setpoint test at 14.00 WIB and 20.00 WIB, the settling time was 801 seconds and 975 seconds, respectively. The 60 °C setpoint test at 14.00 WIB and 20.00 WIB found that the settling time was 840 seconds and 1095 seconds, respectively. The steady state error values at the 50 °C setpoint at 14.00 WIB and 20.00 WIB are 0.2096% and 0.2899%, respectively [13].

This planned research applies the web-based concept of pressure the flow of air heat forced convection. The heat generated from combustion in the furnace will be transferred to the air ducts in the furnace. By the blower the air is sucked forcibly through the heating pipe and then into the heating chamber. The airflow that passes through the heating pipe in the furnace will be heated, either by conduction, convection or radiation.

Fig. 1. Grain Dryer Installation Plan.

Fig. 2. Arrangement of Pipes in Furnace.

Fig. 3. Burning Furnace for Grain Dryer Installation.

Air that has been heated in addition to increasing its temperature will decrease or decrease the density so that its speed increases. The blower sucks and presses hot air (gas) into the heating chamber and then heats/drys the rice grains that are above the heating chamber. The water content contained in the rice grains will be absorbed by hot gas/air to a certain state where the gas density will increase, as the air density decreases, this will cause airflow from the drying chamber to the chimney.

III. Research Methodology

A. Research Design

The research will be carried out with the design of a rice grain dryer using the Pressure the Flow of Air Heat Forced Convection method. The dimensions of the drying room to be made are 8 meters long and 4 cm wide which are able to dry 12 tons of rice grain. This research is an experiment and application, the research data will be studied using conduction and convection heat transfer methods.

The rice grain dryer installation that is made is equipped with a web-based information system that is able to provide temperature information data in the drying room and the duration of time required for the drying process in the grain so that the length of drying time can be known with certainty.

This research was conducted in the Kurik district, Wonorejo village, Merauke district, Papua Indonesia.

B. Research Stages

Implementation in the first year, the stages that are carried out are making or building a rice grain dryer installation. The installation has an area of 4 x 8 meters with a maximum capacity of 12 tons of wet paddy. The heating room is made of terraces where the lower room is the heating air space, and the second level is the space where wet rice grains are placed. The rooms are separated by wire ram with the intention that the hot air/gas from the heating chamber at the bottom can flow to the top to heat or dry the rice grains at the top. This room is closed so that the hot air temperature can last before being released into the atmosphere through a chimney equipped with a blower. In addition, the heating furnace is equipped with a thermocouple, a blower suppressing hot air which will be inserted into the heating chamber. The target in the first year is that the installation has been completed and trials can be carried out to obtain the moisture content of the grain and then evaluated to be more efficient and effective.

The target to be achieved is to get good quality rice that can be used by the community for the production process.

IV. Discussion

Rice grain dryer installation by utilizing hot air flow from traditional combustion furnaces, where the furnace is equipped with air ducts (Φ3 inc) arranged in three layers with a total of 14 holes/stem, when combustion occurs, the pipes will heat and automatically the air contained inside will be heated. The air is then sucked in with the help of a blower (Φ73 cm). The hot air is then pressed into the heating chamber and then transferred to the drying chamber. As seen in Fig. 3. From the results of testing the installation of a grain dryer using the forced convection method, the data obtained are as presented in Table I and Table II.

A. Weight Testing per Specimen

From the test results obtained weight measurement data at 90 minutes with a drying time of 720 minutes. The weight of the unhulled grain decreases faster because the hot gas flow is received first and then the heat slowly rises to the top of the pile, but every 3 hours stirring will be carried out so that the drying process can proceed evenly in all parts of the rice grain pile. In this calculation, the sample data taken is the test with a time of 1.5 hours, with a blower rotation of 2400 rpm.

This drying process aims to reduce the water content in the rice grain which before being heated/dried has a water content of 16.3% by taking a sample of 3 kg of grain weight. The drying process must be carried out to reduce the amount of water content in the rice grain in order to meet the standards of the Logistics Affairs Agency (BULOG) which is 14% so that the amount of water content that must be reduced in 3 kg of rice grain is as follows 16.3% - 14% = 2, 3%.

TABLE I: DATA MEASUREMENT OF TEMPERATURE AND HUMIDITY OF GRAIN DRYER TIME DRYER CAPACITY 12 TON

Parameter	Dryer Time (Minutes)								
	0	90	180	270	360	430	540	630	720
Combustion Chamber (^{O}C)	34	159,56	168,62	176,21	184,90	197,57	215,54	232,76	246,21
Heat Exchanger (^{O}C)	30	76,84	84,63	91,34	101,27	108,78	113,92	118,21	123,46
Drying Room (^{O}C)	34	55,4	59,51	64,73	68,66	71,80	77,58	81,24	85,33
RH Drying Room (^{O}C)	68,33	30,33	27,07	25,45	23,02	20,96	18,14	18,02	17,28

TABLE II: PARAMETER DATA OF TESTING RESULTS USING WOOD FUEL

No.	Parameter	Test results	Unit
1	Fuel	Wood	-
2	Putaran Blower	1725	rpm
3	Flue Gas Airflow Rate	2,0	ms
4	Room Temperature	30	C
5	Air Temperature in Heat Exchanger Pipe	174	C
6	Combustion Chamber/Furnace Temperature	450	C
7	Ventilation Temperature	39,4	C
8	Dryer Room Temperature	38	C
9	Dryer Time	12	Jam

The decrease in product moisture content during the drying process can be explained as follows:

The percentage of moisture content on a wet basis is found using (1).

$$m_b = \frac{0,023}{3} \times 100\% \quad (1)$$

$$m_b = 0,766\ \%$$

The percentage of dry base moisture content is found using (2).

$$m_b = \left(\frac{0,023}{0,023+3}\right) \times 100\% \quad (2)$$

$$m_b = 2,248\ \%$$

The amount of air that evaporates is found using (3).

$$m_{air} = 3\ kg - 0,875\ kg \quad (3)$$

$$m_{air} = 2,125\ kg$$

Energy used to evaporate water.

The amount of convection heat transfer from dry air to the product can be used in (4).

$$Q_{ev} = h_c . A_{tot} . (T_{gi} - T_{go}) \quad (4)$$

$$Q_{ev} = \left(8,010580984\ {}^{W}/_{m^2\ .\ {}^{o}C}\right) . (0,15757776\ m^2)\ x\ (118,8\ -\ 78)\ {}^{o}C$$

$$Q_{ev} = 51,501\ W = 0,05150\ kW$$

So that the amount of air energy used is obtained and is determined by (5).

$$Q_{udara} = \dot{m}_u \times c_p\ (\Delta T_a) \quad (5)$$

$$Q_{udara} = 0,04691\ {}^{kg}/_{s} \times 0,05150\ {}^{kJ}/_{kg.\ {}^{o}C}\ x\ (58,9 - 43,6)\ {}^{o}C$$

$$Q_{udara} = 0,03696\ {}^{kJ}/_{s} = 0,03696\ kW$$

The efficiency of the dryer can be determined by (6).

$$\eta_{dryer} = \frac{Q_{Udara}}{Q_{ev}} \times 100\% \quad (6)$$

$$\eta_{dryer} = \frac{0,03696}{0,05150} \times 100\%$$

$$\eta_{dryer} = 0,71 = 71\ \%$$

From these results it is known that in shelf 5 every 30 minutes resulted in a decrease in the weight of the specimen 0.156 g per minute. With the above results it can be concluded that for testing the weight loss of grain, the best results were obtained between 540 and 620 minutes with a weight of less than 15 g. So from 12 tons of wet grain that was dried after a drying process for 12 hours, the amount of water that evaporated for a 3 kg sample was 0.875 kg so that the dry grain weight was 2.125 kg. Total drying of 12 tons of grain to 10.5 tons. The total evaporation of water vapor in the grain is 0.875 x 12000 kg = 10500 kg (10.5 tons). This shows that the heat used for the rice grain drying process can be used optimally where the efficiency of the grain dryer installation is 71%.

V. CONCLUSION

From the research process carried out on the design of the grain drying oven by utilizing the remaining exhaust gas from the Diesel motor, it can be concluded several things as follows:

The number of heating pipes in the furnace can still be increased in number to increase the flow of hot gas that can be transferred by conduction and convection into the heating chamber due to the large diameter of the blower so that it is still possible to increase the air pressure in the heating chamber.

To be able to take advantage of the heat in the oven more optimally in the future, the drying chamber should be closed to keep the heat in the heating chamber from escaping.

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