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Comparison of Rice Drying Thermal Efficiency Using Hot Air Flow with Full and Half Open of Blower Throttle

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ABSTRACT: *This research is a part of a comprehensive study, in order to make an effective, economical dryer for agricultural products in which it has stable and homogenous room temperature. The tested dryer was an indirect contact type which has a seven-level sliding tray type, the width of each tray was 98 x 65 cm, and LPG was as fuel. The aim of this study was to compare the thermal efficiency of grain drying of 28 kg each; first, between the valve openings of full and half open blower throttle; second, the dryer without installed heating fins and without heating air recirculation.Before the drying process was carried out, 28 kg of harvested grain were spread over seven levels of the tray, randomly but evenly distributed. The drying chamber temperature was set in 50-55^{0}C, then the stove was turned on. During the drying process, the temperature of the drying chamber around the temperature sensor was relatively 50-55^{0}C, it was because the thermo controller regulates the work of the solenoid valve automatically so that the fuel rate flows normally or small in order to maintain the flame of the stove large or small and to maintain the temperature of the drying chamber as desired. The drying of 28 kg grain was done twice in which it had a heating air circulation which produced by a 2" blower, with the speed of air flow with a full and half open throttle. The grains on each tray were relocated every 30 minutes to different levels so that grain heating was evenly distributed. During the drying process, the temperature of the outside air and the drying chamber at the odd number tray level were recorded every 10 minutes interval using several digital thermometers. The drying time length was 540 minutes each.The moisture content of the grain was calculated based on the grain samples which was dried using an oven until the water content became 0%, both harvested wet grain and dry grain from the results of drying used the dryer. The data obtained from this study were then used as the basis for calculating the thermal efficiency of the grain drying. The calculation results show that the thermal efficiency of grain drying with full open blower throttle is 25.3%, while the thermal efficiency of drying grain with half-open blower throttle is 35.2%.*

KEYWORDS_thermal efficiency, without air recirculation, full & half open blower throttle.._

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I. INTRODUCTION

Pratiwi (2006), said grains have various characteristics, depend on its variation. Generally, grain subspecies which grow around the world are differentiated into three types, namely japonica, javanica, and indica. Japonica's type mostly grows in Japan. The javanica's grain subspecies has fluffy grain and an amylose content that is not too high, while indica's subspecies has an elongated round shape and mostly grow in the Philippines and India. In Indonesia, the type of rice that is widely planted is javanica.

The grain can be broken down into sections as shown in Fig. 1. Widely, grain parts can be divided into 3 parts. The outer part is called husk. Husk is composed of palea, lemma and glume. The second part is called the bran layer. The bran layer is composed of the outer layer, middle layer, cross-layer, testaandalcuron, while the inner layer is called endosperm.The post-harvest stages of rice include threshing, transporting, drying, gristing, storing and packaging. One of the important post-harvest stages is the gristing process. At this stage, the grain that is ready to be gristed or Dry Grain (GKG) will be processed into white rice that is ready for consumption (Pratiwi, 2006).In nutritious side, rice grains contain 70-75% carbohydrates, 6-7.5% protein, 3% fat, and a little vitamin B2. Carbohydrates and proteins are found in the bran and endosperm layers. The protein content in endosperm affects the soaking of the head rice and the degree of whiteness of the granules. High protein content makes the granules hardso they tend not to break during shredding or heavyweight. Sosoh weight is the level of release of rice bran, seeds and a few of endosperm from rice grains. Assessment of sosoh degree, namely the calculation of the weight of the valve that is released after the optimal water content for grinding is 13-15%. At higher moisture content the grain is difficult to peel, while at lower moisture content grains becomes easily to be broken (Damardjati, 1988).

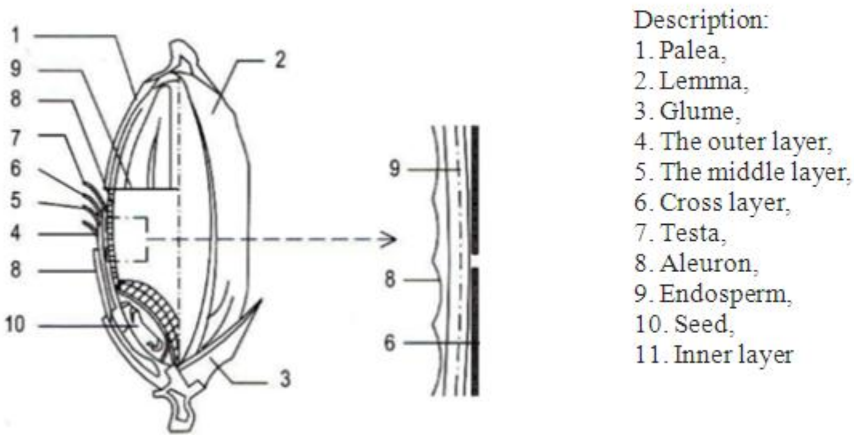

Figure1. Physical characteristics of grain.

Harvested rice usually has a water content of 20-27% or more so it must be dried before storing. In tropical countries, it is usually drying using sunlight until it reaches a moisture content of 14%. In these conditions, grain can be stored for up to 2-3 months. The purpose of drying is to decrease grain water content to 13-14% for long-term storage (Jeffry Laseduw, 2014).The process of drying grain using a machine is to apply hot air as a drying medium. Itsway is the air is flowed in pipes, which are heated by gas or biomass, and then the hot air produced is flowed using a blower, heading into the grain oven space

The heat transfer in the drying process can occur in two ways: direct drying and indirect drying. Direct drying is the heat source associated with the dried material, while indirect drying is heated from the heat source is passed through a solid surface (conventer) and the conventer is related to food (Supriyono, 2003).

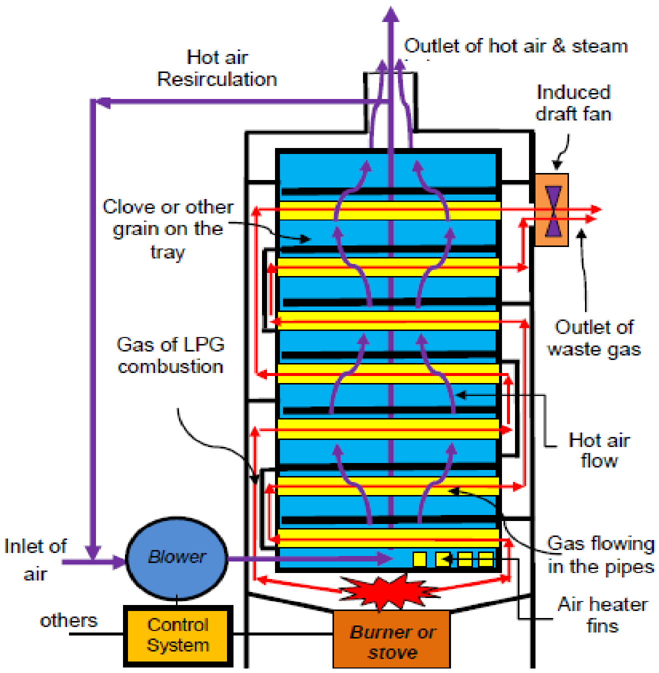

Figure 2. Sketch of the drying process of agricultural products on dryers of indirect contact type which has "Sliding Tray" seven levels, with heating air recirculation

To create an effective, economical dryer for agricultural products in which it has homogen and constant temperature drying chamber, a good design needs to be done by considering various factors. In designing this dryer, the combustion gases from the LPG (Liquified Petroleum Gas) stove are applied as an energy source to heat up indirectly with dried agricultural products. In the study, it uses the heat from the combustion gas as optimally as possible, the dryer is designed using heating fins, recirculated heating air and equipped with heating pipes which are installed in the drying chamber. To produce a constant, homogenous or evenly distributed temperature drying chamber, and also can be adjusted based to the needs of dried agricultural products, the rate of LPG fuel is automatically controlled to produce a normal (large) or small flame.

The designer of agricultural product dryer is a type of indirect contact type which has a seven-level sliding tray. Tray is made of stainless steel perforated plates, while fuel uses LPG in which the supply is regulated automatically using a set of solenoid valve & capillary in order to produce the normal or smallest flow, it would make the stove flame large (normal) or smallest which maintain the temperature of the drying chamber as desired. LPG supply large when the drying chamber temperature has not been reached or small when the drying chamber temperature has been reached. The map of the drying process of agricultural products on this dryer is as shown in Fig. 2.

To figure out whether the dryer good or not and how to improve the characteristics of the dryer better, several studies were carried out several times. The research roadmap can be seen in Fig. 3.

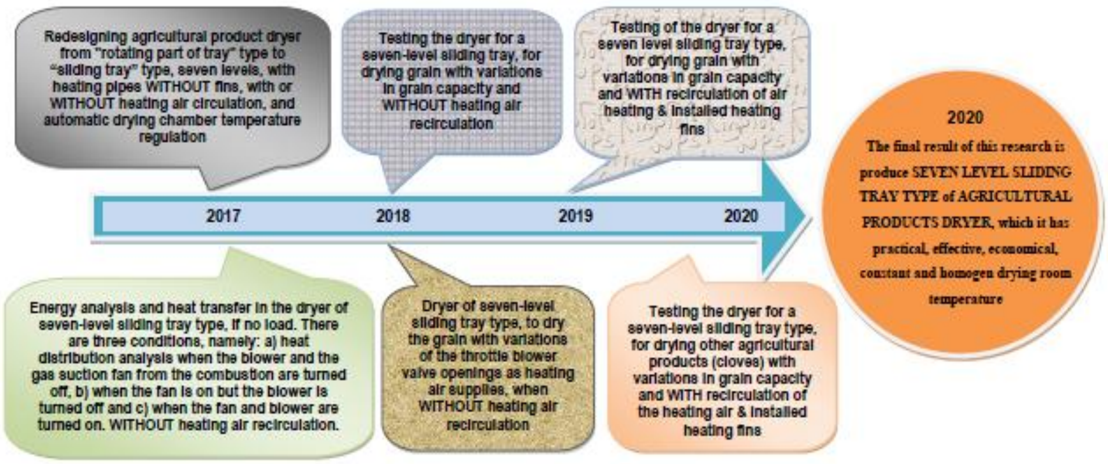

Figure 3. Roadmap of research on the performance of agricultural product dryers, indirect contact types, seven levels of "Sliding Tray" type, using LPG fuel.

The current research is to compare the results of the thermal efficiency of the 28 kg grain drying process twice. The first-grain drying process, with the heating air flow rate produced by the full open blower throttle and the second grain drying, with a half-open blower throttle, and also when the dryer is not installed heating fins, and without heating air recirculation

The aim of this study is to determine the difference of the heating airflow effects to the drying efficiency of 2 x 28 kg grain, on an indirect contact type dryers, seven-level sliding tray type, using LPG fuel, when it occured through the blower throttle which was opened half and full. The dryer which was observed was the tool that was without heating fins installed, and without heating air recirculation.

The use of the dryer of agricultural products is to reduce the water content which was contained in its products. The drying method which was conducted is sometimes different, on the other hands, there was the same or almost the same as one another. Specific treatments were used because some reasons such as products that are sensitive to high drying temperatures, and other reasons, for example, to protect the product so that there was no change in the nature of the product,based on those reasons, various studies were conducted to produce a variety of dryer products that were different from one another. There are numbers of studies on the dryers, described below.

DickySeprianto et al. (2010), conducted research on drying Rosella flowers by using their own design of drying machine which was donated to their partners. The machine works using an electric heater with 440 watts of power, 2 Ampere current, 220-volt voltage. The results of the Rosella flower drying test which were carried out shows that with an air flow rate of 1.2 m / sec, drying temperature of 55^{0}C, and drying time for 14 hours results in a perfect dryness of the flower.Fudholi, A. et al. (2009), in his review said that drying for agricultural and marine products is one of the most interesting and energy-saving applications using solar energy. Various types of solar dryers have been designed and developed in the world. Basically there are four types of solar dryers, namely direct, indirect, and combined and hybrid types.

Susanto J. et al. (2016) have made a dryer of the type of “rotating parts of the tray”, five levels, using dual fuel (LPG or firewood), which still needs some changes, so that the combustion heat can be utilized more optimally. The test results of the tool, for clove drying in the capacity of 15 kg (wet), were successfully dried to 8.04 kg. it required LPG fuel as much as 3.79 kg, from the dryness level of 73.18% to 26.78%, and it required drying time 4 hours 20 minutes, at an average temperature of the drying chamber of 49.71 ^{o}C, and it produced thermal efficiency of 11.57%.Susanto J. et al. (2017) made a dryer which was examined entitle: “*Energy analysis and heat transfer in the type of sliding clove dryer equipped with heating pipes*”. The dryer uses LPG fuel, the setting of the drying chamber temperature is done automatically using a thermo controller & solenoid valve. Although there are still shortcomings, the tool can function properly.

In this dryer, the heat transfer takes place radiationally and conventionally from the gas from LPG fuel combustion, which it is received by a stainless steel plate on the stove. Then a portion of the heat is transmitted conduction to the heating plates made of stainless steel and aluminum, which finally reaches the tray to tray. The air exhaled by the blower is heated by heating plates, then the hot air which produced is used to heat tray-tray and grain, the grain is spread evenly over the heated tray so that the water content of the grain gradually comes out in the vapor phase.

The total heat used in this grain drying process, as in Susanto J. et al. (2017), including:

1. The heat used to heat solid grain, from the atmosphere (environment) temperature to the desired temperature (drying chamber),
2. The sensible heat used to heat water which contained in grain, from the environment temperature to the drying chamber temperature,
3. The heat used to evaporate water (latent heat) contained in the grain,
4. The heat loss through the dryer wall, the heat which comes out through the vent / chimney exhaust, and the loss of the heat lost from the stove to the surrounding which is not absorbed by the dryer.
5. For determining the thermal efficiency of grain drying on this dryer, it is based on energy analysis calculations as follows.

The total amount of heat used in the grain drying process, Q_T, is as follows:

$$Q_T = Q_D + Q_L \tag{1}$$

The heat for heating wet grain (QD), consists of some energy components and explained as follows:

$$Q_D = Q_S + Q_W + Q_{EW} \tag{2}$$

The heat of grain heating, Q_S, Stated by the following equation:

$$Q_S = m_{Sf}\, cp_S\left(T_d - T_f\right) \tag{3}$$

The heat of grain water heating, Q_W, stated by the following equation:

$$Q_W = m_{wf}\, cp_w\left(T_d - T_f\right) \tag{4}$$

The heat of water evaporation from grain Q_{EW}, stated by the following equation:

$$Q_{EW} = \Delta m_w h_{fg} \tag{5}$$

The thermal efficiency of this grain drying device is determined by the equation as follows:

$$\eta = \frac{Q_D}{Q_B} \text{x } 100\ \% \tag{6}$$

II. MATERIALS AND RESEARCH METHODS

The dried material is the harvested wet grain which is dried using this dryer, an indirect contact type, a seven-level sliding tray type, without recirculating the air. The grain dryer used is as shown in Fig. 4, with the specifications, is as shown in Table 1.

Table 1. Specifications of the grain dryer

An indirect contact type,	8. Heating air flow using a blower 2”,
Sliding Tray Type,	9. The combustion gas flow using a mini fan,
LPG as fuel,	10. The temperature setting of the drying chamber automatically uses thermo controller mode: IL-80EN, source 110V/220V, range 0-200 °C, couple CA (K) & solenoid valve, brand: Castel, type: 1020/2A6, ¼” flare, 220/230V, 50/60Hz.
7 tray-level,	
Capacity of max 40 kg,	
The wide of each tray is 98 x 65 cm,	
Number of heating pipes (¾”) is 5 x 7,	

(a) (b) (c) (d)

Figure 4. (a). The dryer in the manufacturing process, there is pipe holes to drain the gas from combustion, (b). The gas flow guide plate on the right side is installed, (c). The gas flow guide plate on the left side is installed, (d). The dryer of an Agricultural product is ready to be tested.

Solenoid valve and the capillary tube, as the LPG fuel flow regulator in Fig. 5 as follows:

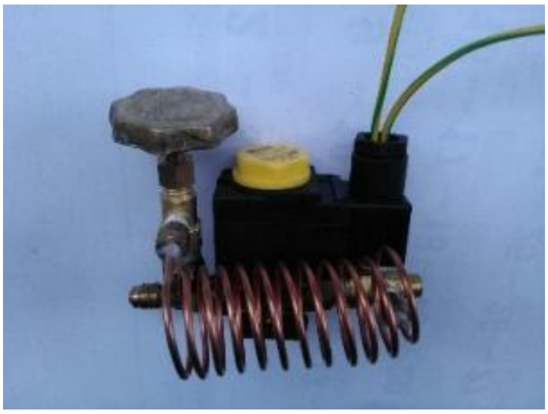

Figure 5. Solenoid valve and the capillary tube, as the LPG fuel flow regulator

The heat transfer mode that occurs is mainly caused of radiation by LPG gas combustion which goes to the stainless steel heating plate; some are passed through conduction to the side aluminum heating plate, then to the heating pipes and tray. The air exhaled by the blower is heated by heating plates, then the hot air produced is used as a grain heater, which is spread equally over seven levels of the tray.

The LPG gas flow rate is regulated by a thermo controller which regulates the work of the solenoid valve to open/close. If the valve opens, LPG gas ignites through the main and by-pass channels, so that the stove turns on large (normal), while the stove turns on smallest when the solenoid valve closes the main channel so that LPG gas only flows through the by-pass channel.

In the first experiment, the dryer was tested on a grain load of 28 kg or 4 kg for each level, the air flow rate was generated from a blower with a fully open throttle, a second experiment was conducted on 28 kg grain load, with a half-open throttle. In the first drying, the initial preparation was to install a digital thermometer sensor in seven points (positions), namely in the tray level 1, 3, 5 and 7, two of outside air, and in the exhaust gas pipe.

The dried material was wet rice from the farmers' crops. Grain was spread randomly, but evenly distributed over seven trays. Before the stove was turned on, the drying chamber temperature was set in the range of 50 - 55^{0}C on the thermo controller. Then the drying process started with turning on the stove (burner). During the drying process, it was carried out the relocation of grain and its tray, each of which was moved to one level below it (unless the first level tray was moved to level seven) every 30 minutes. This was intended so that the level of grain dryness was evenly distributed at all levels.

Taking data of temperature at all points was carried out every 10 minutes during the drying process. The drying process of grain was stopped if the results of visual observations showed that the grain condition was estimated to have reached the desired level of drought, which was 12 to 14%. After observation, the first trial was stopped after the drying process lasted 9 hours or 540 minutes. The second 28 kg grain drying was carried out in the same process as the first drying, with the same drying time, which 9 hours, but the valve valve was opening was a half. The water content contained in grain was determined based on the results of drying the grain sample using the oven, until the level of dryness (moisture content) reached 0%. The grain samples, both wet and dry grain from the results of drying used the dryer.

III. RESULTS AND DISCUSSIONS

The time duration of tool operation to dry agricultural products, at certain working temperatures, in order to obtain the desired level of dryness is determined by various factors, namely the weight / mass of agricultural products, heating air velocity (throttle valve blower opening), and ambient air temperature. For that reason, it is necessary to do a continuous experiment in order to sufficient references on this tool.

The environmental air condition at the first 28 kg grain drying process data taking, showed that the temperature of the dry bulb averaged around 29.0 ^{0}C and the temperature of the wet bulb was 27.1 ^{o}C. In this test, heating air circulation was produced by a 2 "blower with full airspeed (full throttle opening). The grain drying process was carried out for 540 minutes until there was a decrease in grain mass from 28 kg to 24,045 kg, and it required consumption of 0.916 kg LPG. While the second 28 kg grain drying process, the ambient air condition showed that the temperature of the dry bulb averages around 29.4 ^{o}C and the temperature of the wet bulb was 27.2 ^{o}C. In this test, heating air circulation used half the speed (half open throttle). The second grain drying process was also carried out for 9 hours until there was a decrease in grain mass from 28 kg to 22.341 kg, and it required consumption of LPG as 0.910kg

To determine the wet grain content of the crop as well as the results of drying using this dryer, the sample of grain was taken to be dried using the oven. Grain samples were taken from each tray level weighing 5 x 7 x 20 grams and then dried using an oven at a temperature of 110 ^{o}C, until the grain decrease. it means the water content was zero (considered completely dry).

From the results of the experiments shows that the temperature of the drying chamber at the lower level is very high, when it compared to the upper level. The radiation factor by the heating plate is very influential in this case, besides the speed of increase in temperature also is very sharp in the lower drying chamber compared to the top. Other influences were caused by greater absorption of convection and conduction heat at the lower level. In fact, there is a high-temperature difference between the top level drying chamber and lower level. The grain was being relocated to a different tray in order to get equal drying.

Table 2. The Results of 28 kg grain drying in 540 minutes.

Grain drying	Valve openings of throttle blower	The average of Temperature in the drying chamber (^{o}C)	LPG fuel consumption (kg)	Initial water content (%)	The final water content of grain (%)	Thermal efficiency (%)
1	Full open	49.80	0.910	27.60	15.57	25,3
2	Half open	52.42	0.916	27.50	9.14	35.2

The average drying room temperature is 49.80 ^{o}C& 52.42 ^{o}C (for each the first & second drying). The results of the calculation of water content (moisture content) on crop (wet) grain and after drying using the dryer, as well as the thermal efficiency of drying the first and second 28 kg of grain, are presented in table 2. Thus the results of drying this grain can be said to be too dry based on the limit of dry grain. Besides that, the calculations also show that the rate of drying of the first grain per hour is 1.326%, and for the second grain drying is 2.040%.

From the calculations show that the first 28 kg grain drying process, when using the air flow rate with a half-open blower throttle, results in a higher thermal efficiency value than when using the fully open throttle. It shows that when the air flow rate is low, the absorption of gas heat from combustion by air is greater; it is indicated by the air temperature in the higher drying chamber when compared to the second grain drying.

IV. CONCLUSIONS AND SUGGESTIONS

The conclusions obtained from this study are as follows :

The time duration of the first drying of grain with a capacity of 28 kg, with a full blower throttle valve opening, is in 540 minutes, it consumes 0.916 kg of fuel, and it decreases grain moisture content from 27.60% to 15.57%, while for the second grain drying of 28 kg, which has 540 minutes long, with half open of the blower throttle, it consumes 0.910 kg of fuel, and it decreases grain moisture content from 27.50% to 9.14%,

The dryer thermal efficiency for 28 kg grain drying capacity, when the air flow rate with full open of blower throttle is 25.3%.The dryer thermal efficiency for 28 kg grain drying capacity, when the air flow rate with half open of blower throttle is 35.2%.

There are several things that need to be considered in order to improve the performance of this dryer and to overcome / reduce the temperature difference of the drying chamber which is quite large, so that the drying of agricultural products is more evenly distributed. One of them is doing heating air recirculation method which is essential to be done.

NOMENCLATURE

Q_B = heat from fuel combustion of the LPG consumption over grain drying prosses, (kJoule)
Δm_w = mass of wasted water during drying, (kg)
= mwf - mwe
m_{we} = water mass in grain at last (after drying), (kg)
h_{fg} = latent heat of evaporation (kJoule/kg)
m_{wf} = mass of water content in grain, (kg)
cp_w = specific heat of water, (kJoule/kg.^{o}C)
m_{Sf} = solid grain mass, (kg)
cp_S = grain specific heat, (kJoule/kg.^{o}C)
T_d = dry grain (heating chamber) temperature, (^{o}C)
T_f = initial wet grain temperature, (^{o}C)
Q_S = the heat of solid grain heating, (k Joule)
Q_W = the sensible heat of heating water contained in grain, (kJoule)
Q_{EW} = the latent heat of water evaporation from grain, (kJoule)
Q_D = the heat for heating wet grain, (kJoule)
Q_L = the loss heat (no calculated), (kJoule)

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