Study on Paddy Drying Using Husk Stove as a Heater Drying Air

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Abstrak

It has been studied to dry the wet threshed paddy with 25.5% moisture content to be 14% moisture content for safe storage purposes. The dryer is simple construction, so that it can be made by the farmer himself. In this study, it is demonstrated two methods to calculate the amount of drying air needed in drying process i.e: calculation using psychrometric chart and using energy balance, both calculations give a similar values. The comparison of drying times between drying by dryer equipment and by field drying in the sun gives half time advantage for using dryer equipment

Keyword: paddy drying, moisture, psychrometric, energy balance, dryer equipment

Introduction

The staple food of the people in Asia as well as in Indonesia is paddy. The process involved to produce includes harvesting, threshing, drying, storing, and milling the grain. Drying is very important because, the moisture content must be low during storage to prevent the grain from being spoiled by fungi and insect which thrive in warm moist conditions.

Based on the data of Indonesia Central Body of Statistics 2005, Indonesia produces paddy 54 million ton/year. Since the husk contain in paddy about 20÷30%, then production of husk is 11 million ton/year. To destroy husk waste by burning and burying under the soil will pollute the atmosphere and the soil as well. This study is to make use of the husk waste as a fuel to heat air for drying process.

According to [Bakker, B., dan Hall, A., 1975], the moisture content of paddy after harvesting is usually 24%, while for safe storage the moisture content of the grain should be about 14%. Above of this value, the paddy will be suffered by fungi and insect development moreover increasing rodents and mites infestations. The excess moisture must be removed through some drying process

Sun drying of paddy as traditional method used by the farmer will cause several losses such as: bird attack, dust pollution, uncertain weather conditions especially in rainy season. To reduce several such considerable losses, it has been constructed a paddy dryer using husk as fuel to heat air for drying. The design of the dryer is simple, so the farmers enable to construct with their own. This study is carried out to explain the important parameters involved in drying process

Metodology

The drying of a column of grain can be considered an adiabatic process. This implies that the heat required for evaporation of the grain moisture is supplied solely by the drying air, without transfer of heat by conduction, convection or radiation from the surrounding. As the warm air passes through the wet grain mass, a large part of the sensible heat of the air is transformed into latent heat as a result of the increasing amount of water held in the air as a vapor.

Theoritical Background

The drying process is to remove the moisture from the wet grain by drying air and the drying air is commonly a moist air. The moisture from the grain can be picked up if the grain has a vapor pressure higher than in the air. Thus, there are a correlation between properties of wet grain and moist air.

The moisture content in the grain is used as a parameter of grain's grade. The percentage moisture content of a sample grain in wet basis (w.b) is defined by the formula:

$$M = 100\,(w - d)/w \quad [\%] \qquad (1)$$

Where: w = the mass of the wet sample, and d = the mass of the dry grain in the sample The quantity of water removed from the grain can be defined as:

$$m_w = w_i \frac{(M_i - M_f)}{(100 - M_f)} \text{ [kg]} \qquad (2)$$

where: M_i and M_f are initial and final percentage of moisture content in the grain respectively, and w_i is the initial mass of the paddy to be dried.

Since the drying air is moist, there are some thermodynamic terms employed in describing moist air properties which are defined as follows:

Relative humidity: $\emptyset = p_v / p_s$ [%] (3)

p_v = actual partial pressure of water vapor in the air

p_s = saturation vapor pressure of water vapor at the same temperature.

This value is very important in drying because it is the main parameter determining the equilibrium moisture content of grain, and also it determines how effectively the air can dry the grain. If the vapor pressure in the grain higher than vapor pressure in the drying air then the grain will lose of its moisture, and when both of the pressures are equal the grain moisture content remains constant.

Humidity ratio: $\omega = 0.622\ \emptyset \frac{p_s}{p_d}$

[kg H_2O/kg dry air] (4)

p_d is the partial pressure of the dry air.

Energy balance for drying:

$$m_w L = m_a C_p (T_i - T_f) \qquad (5)$$

m_w = mass of water evaporated from a given quantity of grain [kg]

m_a = mass of drying air [kg]

C_p = specific heat of moist air [kJ/kg.K]

The specific heat depends on temperature and relative humidity

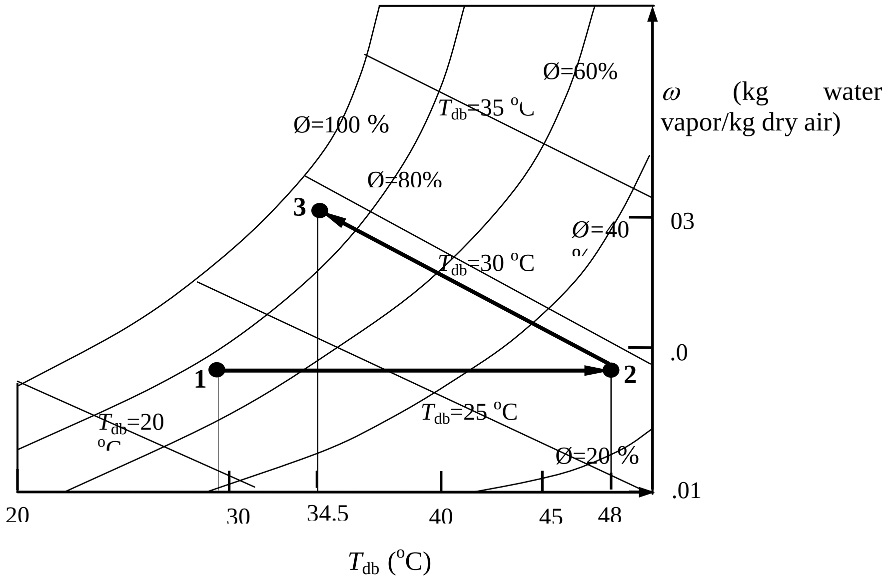

Figure 1. Paths on psychrometric chart illustrating heating and drying processes

L = specific latent heat of vaporization of water from the grain. Water to be evaporated from grain instead from a free water surface needs more heat. As approximation [Exell, R.H.B., 1980], its value can be taken to be 2800 [kJ/kg]

T_i and T_f = initial and final temperatures of drying air respectively [°C]

Thus, the Eq. (5) clarify that in the dying process the latent heat of vaporization of water in the grain is exchanged for sensible heat of grains and drying air.

- Mass of air for drying

  The amount of water m_w to be extracted from 1 kg grain is calculated from Eq. (2), while the mass of air required for drying may be estimated from energy balance Eq. (5).

- Quantity of air for drying: $V = m_a \frac{RT}{P}$ (6)

  R = 0.291 kPa m^3/kg K, P [kPa] and T [K] are the atmospheric pressure and temperature respectively, m_a = mass of drying air [kg]

- Psychrometric chart

  The themodynamic properties of the dry air and water vapor mixture are frequently needed in analyzing grain-drying problems. The Eq. (1) to (6) are used to calculate the required air flow based on initial moisture content wet basis to a final noisture content of the grain with the specific ambient air temperature and relative humidity. To avoid the frequent necessity of making the time consuming calculations, special chart containing the values of the most common thermodynamic properties of moist air have been prepared, and this is called psychrometric chart as shown in Fig. 1.

The horizontal axis of the chart represents the air temperature T_{db} (dry bulb temperature), and the vertical axis represents the humidity ratio ω. The curves drawn on the chart are relative humidity ϕ. The constant wet bulb temperature T_{wb} lines are straight and make sharp engles with the vertical axis.

In order to avoid deleterious effect on the product during drying process [Bakker, B., dan Hall, A., 1975], it is recomended that the drying air temperature must be kept in the range of 43.4 ^oC to 51.7 ^oC. In this study, the ambient air used in drying before entering the paddy bed is heated from the atmospheric temperature until 48 ^oC.

The heating process is shown on Fig.1 as path (1 – 2), the ambient air is heated without the the addition or removal of water, so that the enthalpy of the air will increase but its humidity ratio remains constant and its relative humidity will be reduced. This heated air is then used to remove moisture from a bed paddy. The point (1) represents the temperature and humidity of the ambient air and point (2) represents the temperature and humidity of the air it first comes into contact with the grain.

The drying proses is indicated by the line (2 – 3) as a line parallel to the wet bulb lines. This is because of the grains and the air to cool just as the wet bulb thermometer in psychrometer is cooled below the temperature of the dry bulb temperature. During this process there are an increase in the humidity ratio and relative humidity of the air.

Paddy Dryer Construction

The dryer construction is as shown in Fig. 2, and made of sheet zink. It consists of furnace compartement 3 as a room to burn husk, drying compartment 6 for box of the paddy bed.

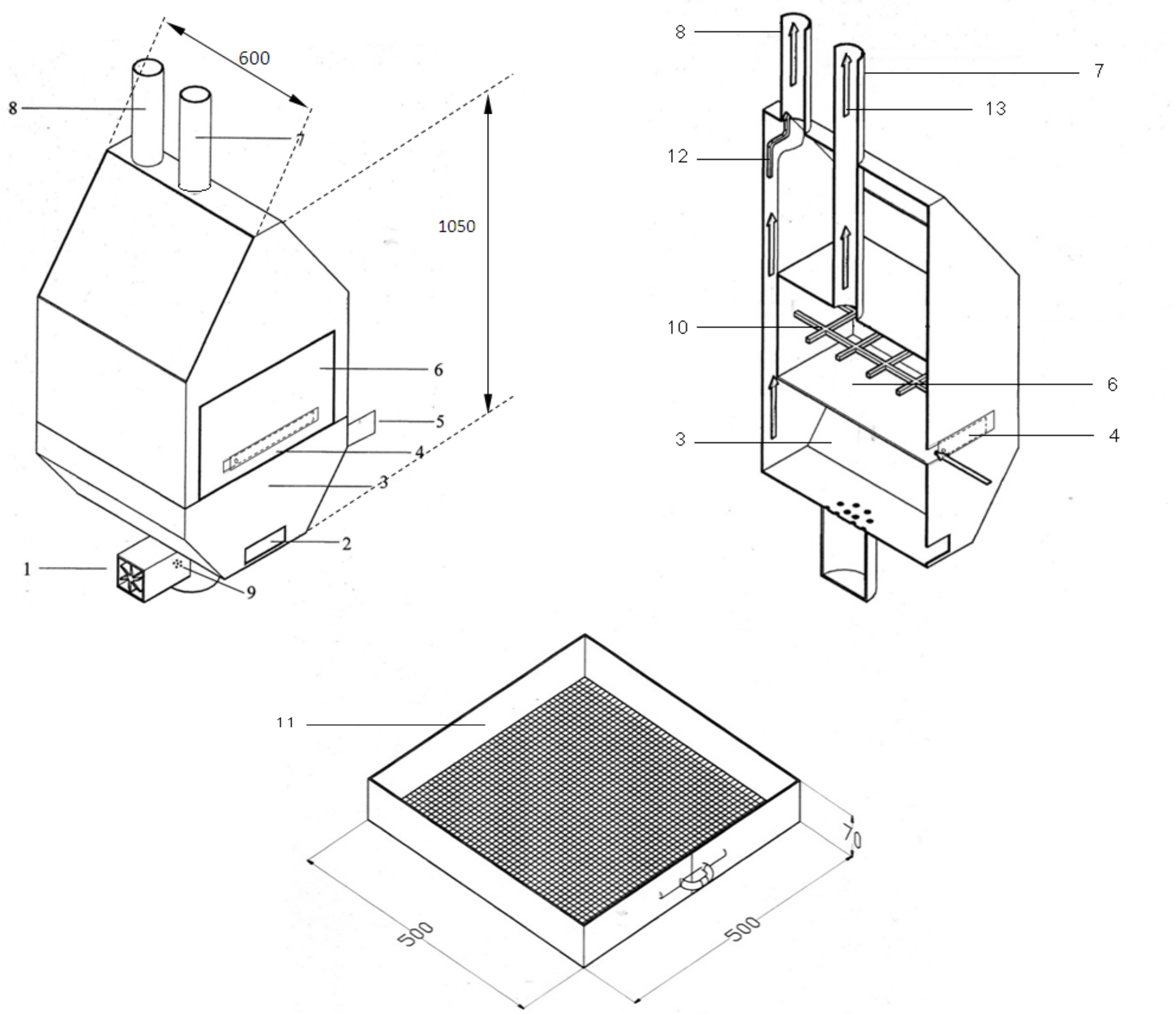

Figure 2. The drier designed for experimental purposes
1.Blower for air 2.Gate for husk ash 3.Furnace compartment 4. Gate for entering drying air 5. Gate for feeding husk 6.Drying compartment 7.Air chimney 8.Flue gas chimney 9.Air channel for combustion 10.Paddy box 11.Drying rack 12.Flue gas 13.Drying air

The bottom of the box 11 is made of wire gauze as perforated material which allows the heated air to pass through paddy bed in the box easely, but does not allow the paddy to pass through. The ambient air enters into the gate 4, flows over heated zink sheet, and the air is heated. Before the air temperature reaches the required temperature the air is letted to flow through the air chimney 7. The flue gas from furnace flows through chimney 8.

In this experiment, to heat the air takes time about 10 minutes to reach the temperature 48 ^{o}C. As the drying air reach temperature 48 ^{o}C, the paddy box filled with paddy is inserted into drying compartment, and then drying process is started. During drying the paddy is stirred at least once to obtain uniform drying. The drying is stopped if the moisture content of paddy reaches 14%. To dry the 7.5 kg paddy takes time 4.37 h.

Calculations and Analysis

At the begining of heating process at state point (1) on Fig. 1, ambient ait temperature T_{db1} = 28 ^{o}C and with relative humidity ϕ_1= 72 %. From psychrometric chart, its humidity ratio ω_1 = 0.0172 kg H_2O/kg d.a. The heating at constant humidity ratio is preceded until state point (2) where the air temperature increases to T_{db2} = 48 ^{o}C, its relative humidity decreases to ϕ_2 = 24.38 %. The point (2) is the initial point of drying process, this heated air is then used to remove moisture from a bed paddy having a moisture content of 25.5 % wet basis to 14 % wet basis at point (3). The equilibrium relative humidity ϕ_3 = 73.46 % is reached, the temperature of drying air reduced to T_{db3} = 33 ^{o}C, and the humidity ratio increases to be ω_3 = 0.0236 kg H_2O/kg d.a. The humidity ratio of the drying air is to rise $\omega_3 - \omega_1$ = 0.0236 – 0.0172 = 0.0064 kg H_2O/kg d.a.

Using Eq. (2), the amount of water to be extracted from 7.5 kg of paddy is:

$$m_w = 7.5\,\frac{(25.5-14)}{(100-14)} = 1.003 \text{ kg}$$

It follows from the definition of the humidity ratio, that the mass of air needed for drying is: 1.003 ÷ 0.0064 = 156.72 kg. Equation (6) shows that the volume of air needed when P = 100 kPa, T = 301 K (28 ^{o}C) is 137.3 m^3.

The air needed for drying can also be calculated from energy balance Eq. (5). We already have m_w = 1.003 kg. L = 2800 kJ/kg, and the value of C_p based on calculations involving temperature and relative humidity is 1.015 kJ/kg ^{o}C, T_i = 48 ^{o}C and taking a mean value of $\frac{33+28}{2}$ = 30.5 ^{o}C for T_f, we obtain $m_a = \frac{1.003 \times 2800}{1.015\times(48-30.5)}$ =158.1 kg. In view of the aproximate calculations, this is satisfactory agreement with the value 156.72 kg determined from psychrometric chart.

To dry the paddy in open air at atmospheric temperature 34.5 ^{o}C, 7.5 kg paddy would take times 8.5 h for drying, while to dry the same amount of paddy in above equipment will take times 4.4 h. Therefore to use paddy drying equipment mentioned above, will give an advantage in drying process.

Conclusions

From the study, one can conclude that:

1. The amount of drying air needed which is calculated by using psychrometric chart and caculated by energy balance between moisture removed from the wet paddy and sensible energy of drying air gives a similar values
2. The comparison drying times between drying by dryer equipment and by field drying in the sun, it gives half time advantage for using dryer equipment

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