International Journal of Mechanical Engineering Research and Development (IJMERD), ISSN 2248 – 9347(Print)
ISSN 2228 – 9355(Online),Volume 1, Number 1
January - April (2011), pp. 47-54

IJMERD

EXPERIMENTAL INVESTIGATION OF AN INDIRECT TYPE OF NATURAL CONVECTION DRYER FOR THIN LAYER PADDY DRYING

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ABSTRACT

Selection of appropriate technology for drying of agricultural produce by using biomass has become a more reliable option in the developing country. In the present scenario, drying through natural convection grain dryer is an important alternative in the village level. This paper presents the development and performance evaluation of the natural convection grain dryer for drying of paddy in thin layers (approximately 2.5 cm to 5.5 cm height on drying tray).Experiments were conducted with wet paddy in four different batches, containing 10 kg, 15 kg, 20 kg and 25 kg respectively**.** The amount of moisture transfer from paddy was studied with time by burning different amount of biomass and the results were compared for different thickness of paddy layers. Average moisture content, was reduced from 30.5% (wb) to14.69% (wb) in the experiment. The dryer developed in the present study will be useful for the small cultivators.

1. INTRODUCTION

The importance of renewable sources of energy is increasing day by day throughout the world. Many steps are taken to extend the technology based on renewable energy towards the end users like farmers to enhance their productivity [1].

For drying agricultural products the two main renewable energy sources used are solar and biomass [2]. Most of the rural areas of developing countries uses biomass particularly fuel wood, as the common source of energy. Fuel wood is a natural source of energy, if used can be balanced by new plantings [3]. There is a need of simple, affordable combustion devices which burned the fuel wood efficiently and used for drying the agricultural products. The proper utilization of these sources in drying can reduce the drying time and improve the product quality compared to open sun drying [2].

The traditional method of drying in most of the developing countries is open sun drying by spreading the paddy on the ground which often results in food contamination and nutritional deterioration which results in degradation of product quality [4].

Hence, the product is not marketable in domestic and international market [2]. In most of the tropical region around the world, some food products are harvested and collected during winter and rainy seasons having high moisture content. Therefore adopting the right drying technique is important in the process of drying in the tropical regions [2]. The problems related with open sun drying can be solved by using solar dryer and biomass dryers, which are mostly classified as natural convection type and forced convection type [4].

The availability of conventional electricity supply and sources of nonconventional energy are difficult and expensive in rural areas of developing countries due to which the use of forced convection type solar dryer is not a simple task. The use of electrical heating systems and fans are not popular for drying of agricultural products [5]. Due to cheap and simple operation, natural convection types of dryer are most popular for drying in the developing countries [6].

In contrast to other solar technologies solar dryers are difficult to accept by the commercial producers due to complexity and dependence on many other factors. Particularly in the rainy seasons and in the night time it is hard to use the solar dryers. Since biomass particularly fuel wood is the leading energy source in the rural level it is better to use dryers that can use biomass for drying the agricultural products in rainy seasons as well as night times [3].

A review of the literature indicates that there have been attempts to overcome the limitations associated with simple natural convection solar dryers. Reference [7] used a saw dust burner to provide heat during rainy seasons and at night. The burner was designed such that it can supply 400 w/m^2 of energy to the drying cabinet, and used steam as the heat transfer medium. The saw dust burner was constructed as a separated component.

Reference [8] reported a dryer which used biomass burner for air heating and using blower through electricity corresponding to a thermal output of 112 kw. The limitation associated with this dryer is that it cannot be used in the areas where electricity is not available. Reference [9] developed an indirect solar dryer with a backup gas burner. They found out that the drying time could be decreased by the inclusion of the backup heater. Reference [3] designed and developed a direct solar dryer and included biomass-backup heater. The thermal performance of the system was satisfactory.

In this work, an indirect type simple natural convection dryer using biomass only was designed and constructed. Drying performance of the same was investigated with different layers of paddy. The system has been evaluated under Guwahati (India) climate, for drying paddy. Results show that the dryer is capable of reducing the moisture content of paddy from 30.5% to 14.69% in average. Further drying efficiency of the dryer was found to be 15.14%.

2. DESIGN AND OPERATION OF THE DRYER

2.1 Description of dryer

The dryer was fabricated for drying of paddy and other products. A complete picture of biomass dryer are shown in Fig. 1(a, b, c and d)

The biomass burner is designed primarily for fuel wood. An indirect heating system was used and precaution was taken to avoid the mixing of flue gases from the chimney and the drying air. This protects the product from contamination by smoke of the flue gas. A conical shape biomass burner(or furnace) of mild steel has been made as shown in figure, having bottom diameter of 60 cm and top diameter of 30 cm through which exhaust pipe of galvanized iron of diameter 6.35 cm and length of 2 m is connected horizontally. The flue gas exhaustion takes place through a 1.8 m length of 6.35 cm diameter pipe connected vertically. The conical furnace is kept on a rectangular stand (base) of 61 cm× 61 cm× 22 cm is covered from three sides. Only front side is opened and there is a fix projection of 30 cm to the outside from the front. A moveable ash tray of 60 cm×60 cm×2 cm is placed on the projection for the removal of ash after burning of biomass. The biomass burns on a perforated plate having dimension 59 cm×59 cm, which is kept on the top part of the stand. A cover plate is used to cover the projection of 30 cm. The conical furnace, rectangular stand; ash tray, cover plate and biomass burning plate are easily disassembled to different parts when required for maintenance. For the feeding of biomass from the outside of the wall into the conical furnace, an inclined thin circular pipe whose one end of diameter 20 cm is connected to the conical furnace . The other end of diameter 13.5 cm is kept on the small opening of the wall. A brick chamber of dimension 1.45 m×1.17 m×0.9 m encloses the biomass burner was constructed. There were eight rectangular holes out of which, six are along the length and two are along the width of brick wall perimeter at ground level for fresh air entry. The wire meshed drying tray provides an effective drying area of ~1m^2. The temperature of the drying air can be controlled by maintaining the combustion in the burner.

Figure1. a. Base of the biomass dryer with biomass burning tray and ash tray.

Figure1. b. Furnace of the biomass dryer with exhaust pipe.

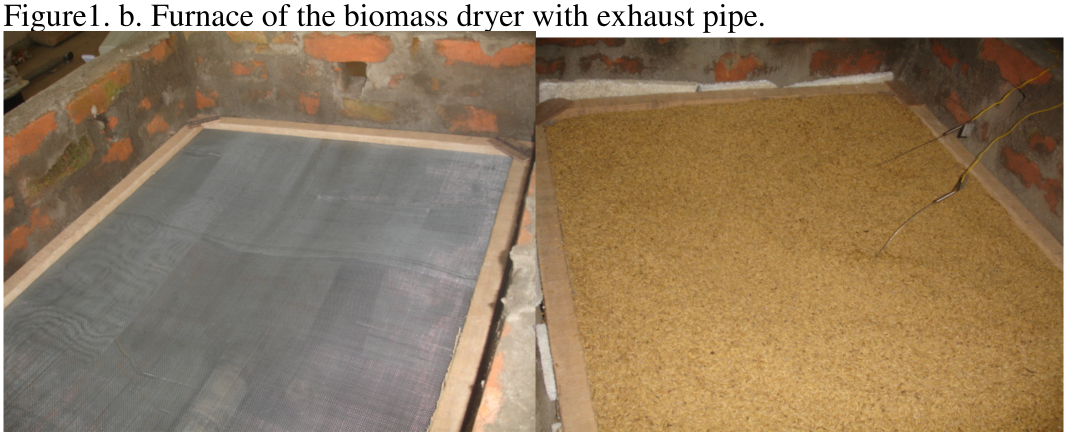

Figure1. c. Drying tray of the biomass dryer.

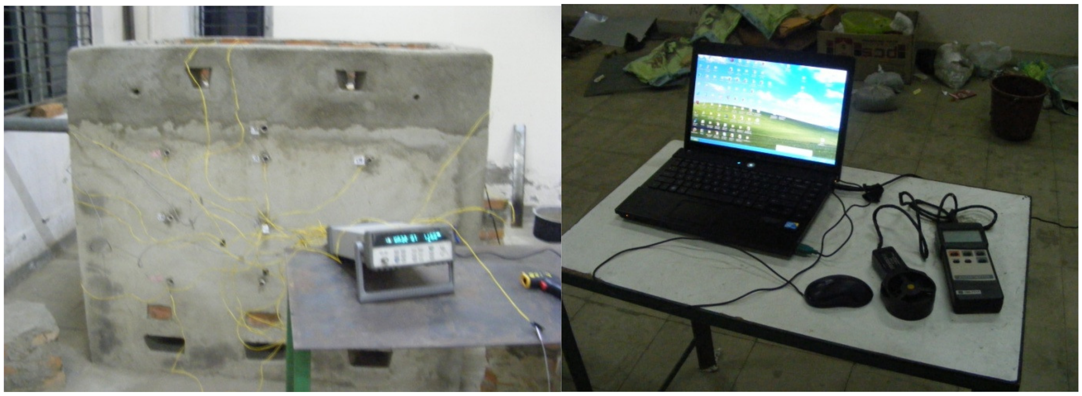

Figure1. d. Biomass dryer.

2.2 OPERATION OF DRYER

The dryer used for this study is designed to make use of biomass energy. Drying parameters were observed at five different points i.e. at center and four corners of the tray. When biomass burns, the surface of the conical furnace gets heated up which in turn warms the surrounding air. The heated air rises up by natural convection, passing through the drying trays and picking up the moisture. This action reduces the pressure inside the dryer and the ambient air is drawn into the dryer through the inlet of holes in the brick chamber. A continuous flow of air is thus established. The temperature inside the dryer is controlled by controlling the feeding rate of the fuel wood in the biomass burner. The novelty of the dryer is that it can be operated by even a unskilled laborer.

3. EVALUATION OF DRYER

The dryer was installed in the laboratory of Centre for Energy, Indian Institute of Technology Guwahati. Four separate trials were conducted by taking four different weight of the paddy (10 kg, 15 kg, 20 kg and 25 kg).

The following studies were carried out:

- To evaluate the amount of moisture transfer with time for different weight of paddy by burning various amount of biomass and the results were compared for different thickness of paddy that were being dried at different time on the metrological condition of Guwahati, India.
- To evaluate the drying air temperature variation just below the paddy tray inside the dryer by burning particular amount of biomass at different time for various batches of paddy drying .
- To evaluate the drying efficiency of the dryer.

3.1 Instrumentation and observations: - The following parameters were measured during the experiments:

(a) mass of paddy before and after drying (b) amount biomass burnt (c) temperature at different points and (d) level of moisture content and (e) relative humidity. Thermocouples of K-type are used for measurement of temperature. Thermocouples are calibrated before using in experiments. A data logger system with data logger software (Model: 34970A, Make: Agilent Technologies) is connected with thermocouples. Electronic balance (Model: spider 'T'-15-15 FLP, SHYAM, Make: Mettler–Toledo India Private Limited) was used for biomass and sample of paddy measurement. For moisture measurement a grain moisture tester (Model PM-410, KETT electric laboratory) is used. The paddy samples have been taken from 5 different places to obtain the uniformity. Relative humidity of air was measured by hygrometer (Model: THM-B_2).

4. RESULTS AND DISCUSSION

4.1 Capacity and drying time

Four batches of paddy of different amount (in weight) and having different thickness on the drying tray are dried at various times by using the different amount of biomass. It can be noted that the biomass is added to each batch. The heated air from the earlier batch needs less amount of heat input compared to the first batch (starting one) for drying purpose. Average moisture transfer of different batches of paddy with time is given in fig.2.

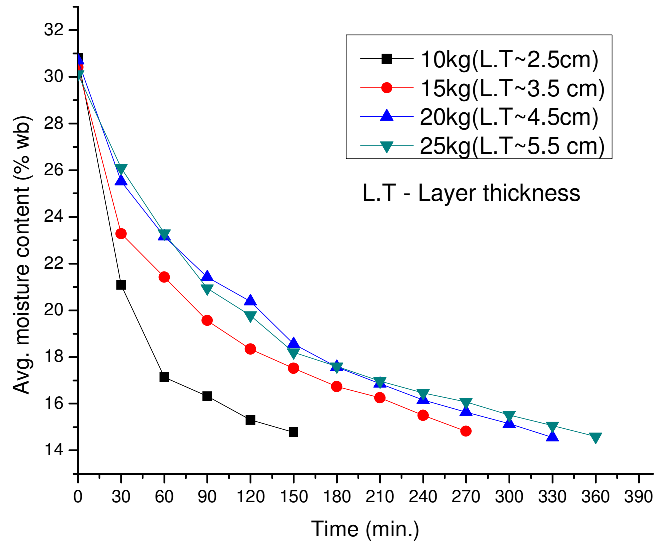

Figure 2 Variation of Avg. moisture content of different amount of paddy with time

First batch contains 10 kg of paddy of thickness ~2.5 cm requires two hours and thirty minutes for the removal of moisture from 30.8 % (wb) to 14.78 %(wb). Two kilogram of biomass was burnt in the furnace to dry 10kg of paddy. It is observed that the initial moisture removal from the paddy in the beginning of the drying process is fast due to the removal of surface moisture. Surface moisture will readily evaporate when the grain is exposed to hot air but internal moisture evaporates slowly as it has to move away from the kernel to the outside surface due to surface forces (capillary flow) as shown in figure [11]. Second batch contains 15 kg of paddy of thickness ~3.5 cm and requires 4hrs 30minutes for the removal of moisture from 30.4% to 14.82%. Two kilogram and 500gm of biomass was burnt in the furnace for the drying of 15kg of paddy. The initial moisture removal for 15kg paddy is less than that of 10kg of paddy due to increase in thickness. Third batch contains 20 kg of paddy of thickness ~4.5 cm will require 5 hrs 30minutes for the removal of moisture from 30.7% to 14.56%. 3kg of biomass was required for burning in the furnace for the drying of 20 kg of paddy. The initial moisture removal of the paddy during the beginning time is fast due to surface moisture removal but it is less as compared to 10 and 15kg of paddy due to increase of thickness. Fourth batch contains 25 kg of paddy of thickness ~5.5 cm will require 6hrs for the removal of moisture from 30.1% to 14.6%. Three kilogram and 500gram of biomass was required for burning in the furnace for the drying of 25kg of paddy. The time required for drying of 25 kg of paddy is more than 20kg, 15kg, and 10kg. Initial moisture transfer is more in case of 10kg than 15kg, 20kg, and 25kg.

4.2 VARIATION OF DRYING AIR TEMPERATURE

The average value of the variation of drying air temperature just below the paddy tray with time are shown in fig.2 (a), (b), (c), and (d) for paddy amount 10kg, 15kg, 20kg, 25kg respectively. When the temperature of drying air reaches above 50^{o} C, paddy is loaded on the drying tray for quality drying. Drying air temperature is measured at four different points just below the drying tray, and then the average value of the four temperatures is considered.

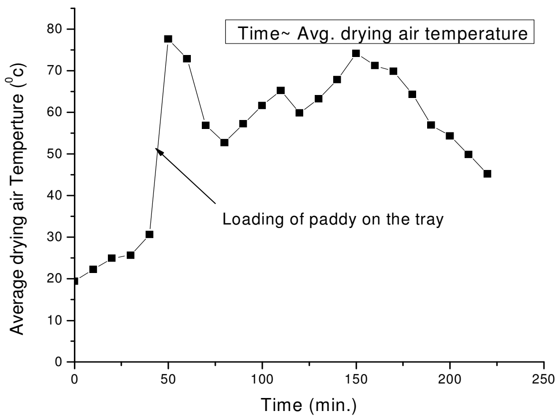

Figure 2(a) Variation of Avg. drying air temperature with time for 10kg of paddy.

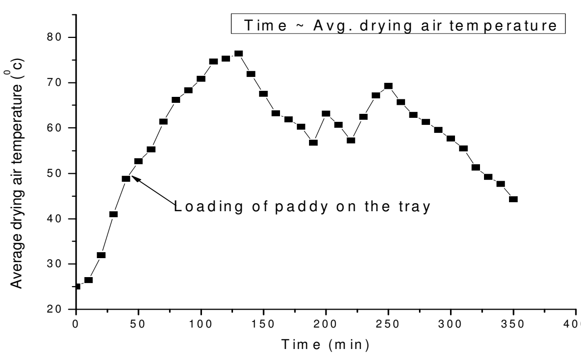

Figure2. (b) Variation of Avg. drying air temperature with time for 15kg of paddy.

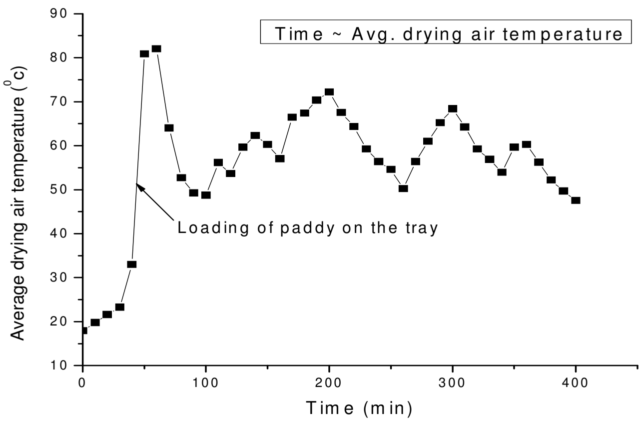

Figure2. (c) Variation of Avg. drying air temperature with time for 20kg of paddy.

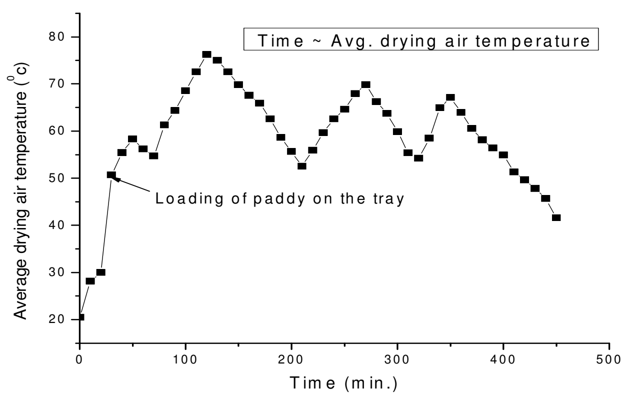

Figure2. (d). Variation of Avg. drying air temperature with time for 25kg of paddy.

4.3 FURNACE PERFORMANCE

During the initial tests of the biomass heater using small pieces of fast burning fuel wood, it was found difficult to control the rate of combustion in the furnace. The temperature inside the dryer quickly rose more than 100°C which is undesirable for drying of paddy. The high temperature drying will affect the quality of paddy [11] and also the combustion could not sustain for a longer time without adding more fuel, which is a disadvantage of the drying process. However, controlling the dryer air temperature is difficult without providing adjustable air inlet valve and generally not suitable for rural application. So temperature inside the dryer is controlled by regulating the burning rate of biomass.

4.4 CALCULATION OF DRYING EFFICIENCY FOR THE FOUR BATCHES

Drying efficiency of biomass dryer is defined as the ratio of energy used to evaporate the moisture in the paddy to the energy input to the dryer by biomass.

$$\eta = \frac{WL}{MC}$$

where η is the drying efficiency , W is the weight of the water evaporated from the product (kg), L the latent heat of evaporation of water (MJ/kg), M is the mass of the fuel in kg and C is the calorific value of the biomass fuel (MJ/kg). The calorific value of fuel wood was 17.619 MJ/kg as measured by bomb calorimeter. The drying efficiency was found to be 15.14%, by burning of 11kg of fuel wood.

5. CONCLUSION

A simple dryer is designed and fabricated with available materials. The developed natural convection biomass dryer is capable of producing drying air temperature above 50^{o} C for paddy drying to a safe moisture level. Certain key design features of the furnace contributed to increase the performance of the dryer are explained. It was found that drying time increases and initial surface moisture transfer decreases if the thickness of paddy increases and amount of biomass required decreases for higher thickness of paddy layer as compared to the former. As explained earlier in section 4.1, the requirement of biomass is less for the subsequent batches after the starting batch with 10 kg paddy. The drying efficiency of the dryer was found to be 15.14%.

The system is predetermined for application on small farmers in developing countries for its low investment and ease of application with better efficiency.

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