



Development of Static Flat-bed Batch Dryer for Small Scale Grain Drying

Lubna Sadaf Anchal¹, Abhinav Dubey^{1*} and Prasanna Kumar¹

¹College of Agricultural Engineering, University of Agriculture Sciences, Bengaluru (560065), India.

Authors' contributions

This work was carried out in collaboration among all authors. Author LSA conducted and designed the experiments. Author AD prepared the manuscript and helped in analysis of data. Author PK supervised the experiments and suggested the corrections in the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

A Static Flat Bed Batch Dryer was developed at Department of Agricultural Engineering GKVK, Bangalore with a capacity of 20 kg and mainly to be used for drying paddy from harvesting moisture content (20 – 22%) to 12% for safe storage. The dryer mainly consists of Blower, Heating chamber, Plenum chamber and drying chamber. Drying characteristics such as drying rate, drying time and temperature of inlet air were studied for paddy grain and results were analysed. The decrease in moisture content, static pressure developed in the dryer and relative humidity in the dryer was studied at two different air flow rates of 1 m³/min and 1.26 m³/min. It was observed that the moisture reduction up to the desired 12% was completed in 90 minutes of operation of the dryer. The relative humidity of drying air inside the dryer as well as the static pressure was found to decrease with time. The developed technology is low cost and can be easy constructed at farm level.

Keywords: Batch dryer; grain drying; flat bed; static pressure; paddy.

1. INTRODUCTION

Grain drying refers to the removal of some of the moisture from grain by mechanically moving air through the grain after it has been harvested [1]. Grain in the field dries naturally as the crop matures, giving up moisture to the air until the grain moisture is in equilibrium with the moisture in the air (equilibrium moisture content). Paddy is usually harvested at moisture content of about 24-26 percent (wet basis), higher during the rainy season and lower during the dry season [2]. Grains harvested at higher moisture content need to be dried immediately in order to prevent spoilage [3]. In terms of its relative importance rice is an important staple food consumed throughout India. The per capita consumption of rice has increased from 13.9 kg/y in 1995 to 14.5 kg/y in 2000 [4] and to 38 kg in 2009, as compared to per capita production of 20 kg paddy/year or 13 kg milled/year [5]. As a living biological material, paddy respire at an increasing rate with moisture content. Paddy respiration is characterised by a decrease in dry matter weight, utilization of oxygen, evolution of carbon dioxide and the release of energy in the form of heat. Respiration is negligible at moisture content of about 12-14 percent [2].

At this moisture content at harvest, paddy has a high respiration rate and is very susceptible to attack by micro-organisms, insects and pests. The heat evolved during the respiration process is retained in the grain and in the bulk because of the insulating effect of the rice husk. This heat increases the temperature of the grain resulting in increased mould growth, fungi, insect and pest infection, which increases the quantitative loss and qualitative deterioration [6]. The way that rice is handled during the drying and storage processes will determine its quality at the point of sale, thereby influencing its value. Rice should be quickly dried down to a moisture level of about 12% for storage, especially if it is going to be stored for several months. Drying facilitates the grain to be stored for longer span and hence fetches good returns for the farmers if the produce is sold in high demand season. Drying and storing rice on the farm can be an excellent marketing strategy. The reduction of grain moisture is done by passing relatively large quantities of dry air over the rice after it is placed in the bin. The quality and quantity of this air determine the final moisture content of the rice kernel [3]. A thin-layer drying is defined as a layer of material fully exposed to an airstream during drying. Kucuk et al. [7] reported that the

thickness of a thin layer can be increased provided there is an increase in the drying air velocity and also if the simultaneous heat and mass transfers of the material are in equilibrium with the thermodynamic state of the drying air. Major types of hot air dryers are designed as bin, batch and continuous flow [8]. There are various versions of the above three types of dryers in use globally [9,10]. In a double stage dryer the drying process is split into two halves, in the first pass it is fast dried to moisture content of 18% and further slowly reduced to desired 14% in the second pass [11]. Pontwane et al. [12] developed fully-automated pilot-scale fluidized bed drying system with capacity of 500 kg/h. Complete drying of paddy with $\geq 28\%$ (w.b.) initial moisture content was attained after 2 passes of fluidized-bed drying at 2 min exposure to 70°C drying temperature and 4.9 m/s superficial air velocity. The total drying time was 2.07 h and 60 min ambient air tempering period (30 min without ventilation and 30 min with air ventilation). Generally, drying of grain requires exposure to an atmosphere of lower relative humidity than the equilibrium value at the grain surface. This can be maintained by passing a hot gas of low relative humidity around the grain, usually in the bed of grain [13]. The in-bin dryers use ambient air with or without supplemental heat. There are also combinations of in-bin and continuous flow dryers, developed within the concept of two stage drying [14].

One of the most conventional methods of drying is deep bed type dryer. In this type of dryer, grain drying is considered as batch process where moisture content, air and grain temperature, and the humidity of the air change simultaneously [13]. The 'specific' air flow rate is the quantity of air passing through a grain mass divided by the volume of grain it passes through (e.g. measured in litres of air per second per tonne of grain [15]). It was observed that as the air passes through the grain mass, the specific airflow rate becomes smaller and smaller, until it reaches a minimum value at the surface of the grain. It is this minimum value of specific flow rate that governs the drying performance of a system, since it defines the time that it takes for drying the grain mass. Air flow rate significantly affected the rate of drying and rice moisture content profiles within the drying column. Airflow has an effect on the quality of the milled product of the rice as intra-kernel material state gradients were created which potentially affected grain fissuring [16]. Thus a need of small scale batch dryer which could be effectively used for drying the grains at

faster rate was realised and hence the static flat-bed batch dryer was developed.

2. MATERIALS AND METHODS

The overall developmental process of the static bed batch dryer was divided into component selection, fabrication and its performance evaluation by drying paddy grain. A batch dryer consisting of a blower, heating chamber, plenum chamber, drying chamber, perforated sheet, grain discharge chute Instruments were used to take the measurements of static pressure, temperature, air flow rate, grain moisture content, relative humidity Static pressure of the air is measured from U tube manometer, it consisted of a measuring scale and plastic tube containing water. Trisense is used to measure the temperature, RH, air flow rate, Kett moisture meter used to measure the grain moisture.

The various components of a static bed batch dryer were as follows

- a. **Blower:** It was used to blow the air to the heating chamber at controlled rate. Centrifugal blowers was selected tp

provide directional air flow by maximizing static pressure, making them optimal for spot cooling and for air flow through a duct. A centrifugal blower of capacity 1.46 m³/min. was selected for fabrication of the dryer.

- b. **Heating Chamber:** It was fabricated with 3 electrically heated coils to generate sufficient temperature for grain drying.
- c. **Plenum Chamber:** A (60×30×15 cm) cuboidal chamber was fabricated to facilitate the movement of air to the drying bin. The purpose of the plenum chamber was to let the air calm down before it enters the air distribution system in order to guarantee an equal distribution of pressure and temperature of the drying air throughout the drying section.
- d. **Perforated Sheet:** constructed using MS sheet with 24 holes per sq.cm., the sheet was placed at inclination of 9° with respect to horizontal.
- e. **Drying chamber or bin:** The function of the drying bin was to hold the grain for drying and in in-store drying also to serve as the storage bin after drying.



Fig. 1. Heating chamber



Fig. 2. Plenum chamber



Fig. 3. Perforated sheet



Fig. 4. Drying chamber



Fig. 5. U-Tube manometer



Fig. 6. Trisense for measuring Temp., RH



Fig. 7. Top view of the developed dryer



Fig. 8. Profile view of the developed dryer

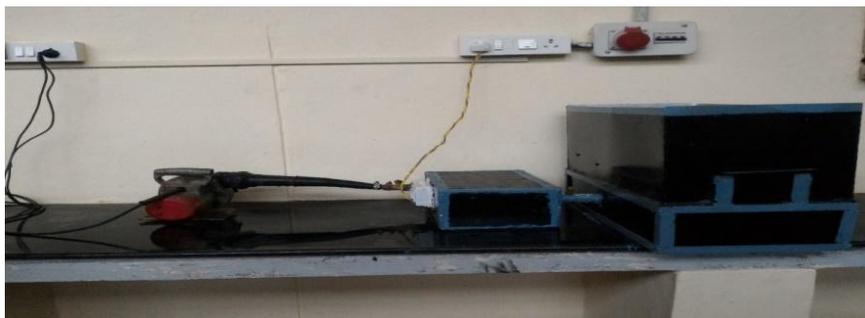


Fig. 9. Front view of the developed dryer

2.1 Fabrication of the Static Flatbed Batch Dryer

A static flatbed dryer is a type of on farm dryer, the dryer was designed and developed based on the anthropometric data for agricultural workers for easy operation of the dryer. In the fabrication process the plenum chamber was fabricated. The drying chamber was designed in accordance was capacity to hold 20 kg of paddy in a batch drying process. The electric heating coils were assembled in the heating chamber of the dryer and connections were arranged. The maximum capacity of the blower was about 1.47 m³/min., it was placed at ground level to blow the air to heating chamber. The air flows in cross direction to the heating coils and flows underneath the drying chamber.

3. RESULTS AND DISCUSSION

The decrease in moisture content, static pressure developed in the dryer and

relative humidity in the dryer was studied at two different air flow rates of 1 m³/min and 1.26 m³/minute. The temperature in the dryer developed was found to be and 60°C and 55°C respectively at selected flow rates. The higher flow rate resulted in lowering of temperature of the drying air. Figs. 10 and 11 shows the reduction in moisture content of paddy with time dried in the developed dryer. It was observed that the moisture reduction up to the desired 12% was completed in 90 minutes of operation of the dryer.

The relative humidity of drying air inside the dryer as well as the static pressure was found to decrease with time. The dryer can be effectively utilised for small batch application of grain drying. The static pressure was found to increase at higher air flow rate of 1.26 m³/min. A decrease in air flow rate signifies easier passage of air through the grain mass.

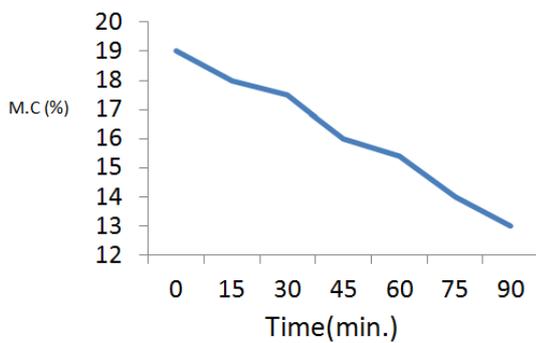


Fig. 10. Moisture content versus drying time at air flow rate of 1 m³/min and temperature 60°C

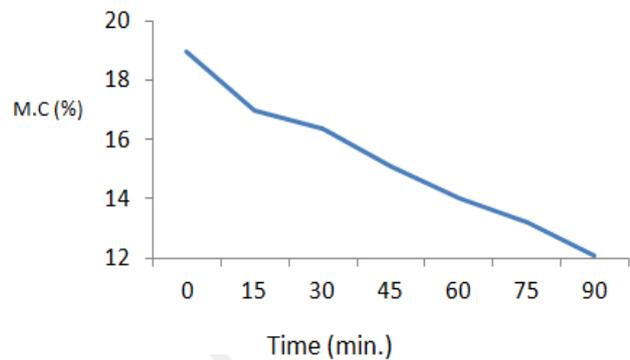


Fig. 11. Moisture content versus drying time at air flow rate of 1.26 m³/min and temperature 55°C

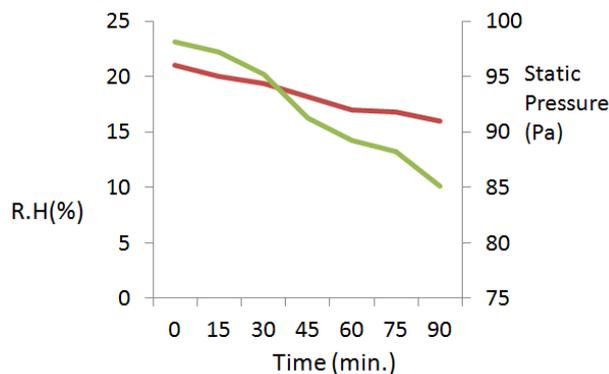


Fig. 12. Relative humidity and static pressure developed in the dryer at air flow rate of 1.26 m³/min and temperature 55°C

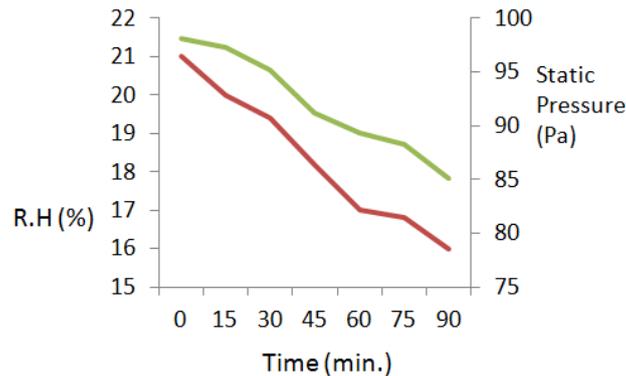


Fig. 13. Relative humidity and static pressure developed in the dryer at air flow rate of 1 m³/min and temperature 60°C

4. CONCLUSION

The developed dryer can be effectively utilised for drying of grains at small scale at places of high relative humidity. Higher temperature during the drying operation however, may affect the quality characteristics of grain after milling operation. Thus temperature regulation should be incorporated during the operation by varying the air flow rate. The developed technology is low cost and easy constructed at farm level. The developed dryer of batch drying systems offers many advantages over sun drying like maintenance of paddy quality, safe drying during rain and at night, increased capacity, easy control of drying parameters and the potential for saving on labour cost.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Wehrspann J. Sizing up grain dryers; 1998. Available: <http://farministrynews.com/> (Cited by Penton Business Media, Inc. September, 2010)
- Lantin R. Post-harvest operations. International Rice Research Institute, Philippines (IRRI); 2006. Available: <http://www.fao.org/inpho/> (Accessed on 20th July 2011)
- Sahay KM, Singh KK. Unit operations of agricultural processing. Central Institute of Agricultural Engineering, Vikas Publishing House PVT Ltd, Bhopal; 2001.
- Ministry of Food and Agriculture (MOFA). Agriculture in Ghana, facts and figures. Issued by the Statistics, Research and Information Directorate, MOFA, Accra, Ghana; 2001.
- Kallai WK. Design, development and evaluation of a continuous-flow mixing grain dryer. Doctoral Dissertation, Kwame Nkrumah University of Science and Technology; 2011.
- Bala BK. Drying and storage of cereal grains. Enfield (NH): Science Publishers; 1997.
- Kucuk H, Midilli A, Kilic A, Dincer I. A review on thin-layer drying-curve equations. *Drying Technology*. 2014;32(7): 757-773.
- Markowski M, Białobrzewski I, Modrzewska A. Kinetics of spouted-bed drying of barley: Diffusivities for sphere and ellipsoid. *Journal of Food Engineering*. 2010;96(3):380-387.
- Wang H. Low temperature and CA storage of rice in bag in China. Paper Presented at the Regional Workshop on Warehouse Management of Bag Storage of Grains, New Delhi, India, 8-17 September 1986. FAOI, UNDP/Indian Ministry of Food and Civil Supplies; 1986.
- Zhang M. Corn drying methods. In: *Food Grain Storage Structures and Methods*, Report on FAO/UNDO/AFMA/CHINA. The Peoples Republic of China. 1988;34-37.
- Szrednicki GS, Driscoll RB. Advances in research on in-store drying. In: Highley, E., Wright, E.J., Banks, H.J. and Champ, B.R. *Stored product protection. Proceedings of the 6th International Working Conference on Stored-product Protection*; 1994.
- Pontawe RJ, Asuncion NT, Villacorte RB, Martinez RC. Pilot-scale fluidized bed drying system for complete drying of paddy.

13. Sitompul JP, Istadi, Widiasta IN. Modelling and simulation of deep bed grain dryers. *Drying Technology*. 2001;19(2):269–280.
14. Szrednicki GS. *Drying Technology*. 2005;23(7):1532–2300.
15. Newman CJ. Specification and design of enclosures for gas treatment. In: Champ, B.R., Highley, E. and Bants, H. J. *Fumigation and Controlled Atmosphere Storage of Grain: Proceedings of an International Conference, Singapore, ACIAR Proceeding*. 1990;25:14–18.
16. Mukhopadhyay S, Siebenmorgen TJ. Effect of airflow rate on drying air and moisture content profiles inside a cross-flow drying column. *Drying Technology*. 2018;36(11):1326-1341.

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