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Measurement of Drying Rates in a Domestic Scale Fluidized Bed Dryer

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ABSTRACT: A domestic scale fluidized bed dryer is designed, fabricated and used to measure the drying rates of wood chips and ground nuts at various operating conditions. Experiments were conducted at two different bed temperatures viz. 100°C and 115°C and also at three different fluidization velocities. The design was carried out using SOLIDWORKS and fabrication was done in a workshop using most basic processes. The purpose of keeping the cost of the facility was achieved. Different drying rates at different times, conditions, and materials were noticed. Drying times were lower for higher fluidization velocities and also at higher bed temperature. However, the influence of fluidization velocity is found to be greater than bed temperatures.

KEYWORDS: Drying, Kinetics, Domestic, Fluidized Bed, Wood, Ground Nut.

1 INTRODUCTION

Fluidized bed technology has been used in industrial dryers for the drying of wet solid particles. Industrial drying operations require a high rate of heat and mass transfer and a high rate of solid transport to or from the dryer. The main advantages of fluidized bed technology in drying application are large contact surface area between solids and gas, high thermal inertia of solids, good degree of solids mixing, and rapid transfer of heat and moisture between solids and gas that shortens drying time considerably without damaging heat sensitive materials. In addition, fluidized solid particles can be easily transported into and out of the dryer by gravity (much like a liquid) and transported elsewhere by pneumatic conveying with less mechanical equipment. Fluidized-bed drying has found many applications in chemical, metallurgical and pharmaceutical industries [1]. In a country like India where grains like cereals are harvested seasonally and consumed continuously; need to be stored properly from insects, pests and fungus formation. The situation can worsen during rainy seasons and high humid conditions. Cooling the grain by ambient air aeration (even in tropical climates) solar cooling' or refrigerated aeration offers many benefits including slowing insect population growth rates, reducing pesticide usage and preserving grain quality. Drying grams, such as paddy rice, to a moisture content of 14% is essential to prevent destructive growth and to maintain germination and milling qualities. Heating grains to 55°C for 15 min is lethal to all stages of insect, fungus development; while at 65°C death is almost instantaneous. Adequate management of insects and moulds that attack and destroy harvested grain has always received less attention. One of the biggest advantages of dried foods is that they take much less storage space than canned or frozen foods [2]. Food quality and safety are other issue which are very important and need to be discussed when drying of food is studied [3]. It is very important to understand basic concepts of drying before heading to the detailed study of this complex phenomenon of heat, mass and momentum transfer. It is useful to note the following unique features of drying which make it a fascinating and challenging area for R&D, not just for food sectors but also for other applications [4]

The objective of the present work to design, fabricate and conduct experiments on a fluidized bed dryer with different samples of food grains and wood pellets and to estimate the drying rates at various operating conditions. Drying kinetics, which can be obtained from drying rates are presently available from Thermo Gravimetric Analysis performed on powdered samples. This study will help in computing the drying kinetics in fluidized bed conditions, which are mostly absent in open literature. The kinetics will aid in better drying models and thereby better dryer design.

2 DRYING KINETICS

Consider the drying of a wet solid under fixed drying conditions. In the most general cases, after an initial period of adjustment, the dry basis moisture content decreases linearly with time, t, following the start of the evaporation. This is followed by a non-linear decrease in moisture content with t until, after a very long time, the solid reaches its equilibrium moisture content, and drying stops [5]. A plot of rate of water vaporisation versus moisture content is the so called drying rate curve. This curve must always be obtained under constant drying conditions. Note that, in actual dryers, the drying material is generally exposed to varying drying conditions (e.g., different relative gas solid velocities, different gas temperatures and humidity, different flow orientations). Thus, it is necessary to develop a methodology in order to interpolate or extrapolate limited drying rate data over a range of operating conditions. These drying kinetics may be obtained from different experimental facilities at various operating conditions [6].

3 MODEL DESIGN FABRICATION AND EXPERIMENTATION

3.1 DESIGN OF MODEL

The model was designed by using solid works software by specifying the shapes, joints and dimensions in which the type of components and dimensions are selected based on availability of components, ease of manufacturing and requirements of the dryer [7].

3.2 FABRICATION

Welding was used to join the MS components and to join the wooden flanges and acrylic tube we have used synthetic resin adhesives and bolts, washers and nuts were used to join the flanges at different places. To make our model stand on the surface we have welded three MS rods of required height with required angle to our model to make it stand straight. Figures 1 and 2 show the Computer Aided Design model and the fabricated model respectively. The major components are the fluidized bed chamber, plenum, blower, electrical air heater and piping. Sand of 500 µm is used as the inert bed material. The bed is supported above the plenum by a stainless steel wire mesh over the distributor plate.

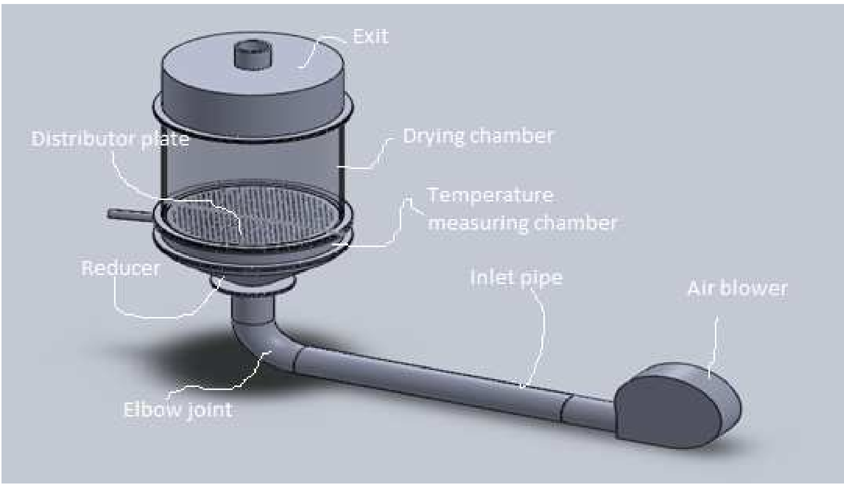

Fig. 1: CAD model with labeling

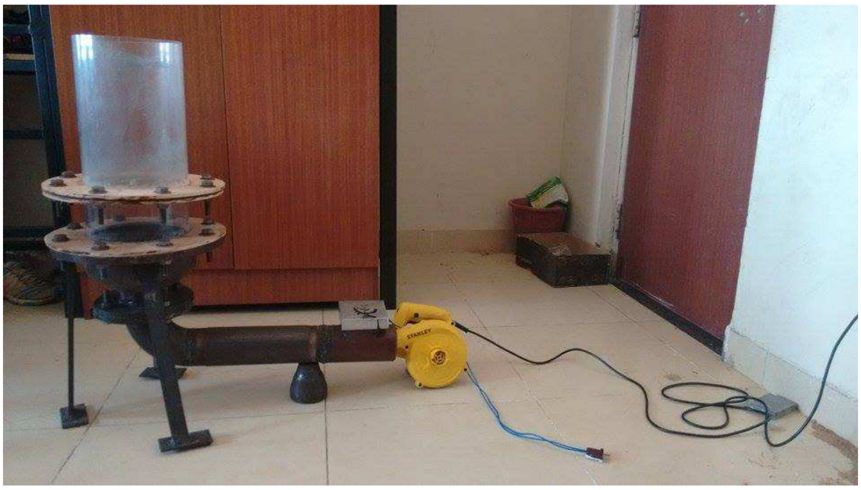

Fig.2: Final fabricated model used for experimentation

3.3 EXPERIMENT DESIGN

As our aim was to study different characteristics involved drying hot air is blown at different temperatures and the mass of samples is measured after dry cooling in desiccator at regular intervals.

For our experimentation we have chosen the samples of wood pellets and groundnuts and determined the mass of the sample with the time interval of 5 minutes and took the readings up to 80 minutes. This was done for 3 different velocities and 2 different inlet temperatures by which the following curves which speaks mostly about the drying phenomena occurring in our model:

1. Mass vs. Time.
2. Moisture removed vs. time.
3. Moisture content vs. time (Drying curve).
4. Drying rate curve: [d (moisture content)/d (time)] vs. moisture content.

3.4 EXPERIMENTAL PROCEDURE

- Place the setup in safe place and preheat the setup to achieve the required temperature.
- Then place the prepared sample inside the holding basket which is placed inside the drying chamber.
- Then the air is blown at the required velocity which is passed through the tubular heater and then to the drying chamber.
- After passing air through certain time measure the mass of the sample after dry cooling.
- Repeat the procedure until no observable change in mass is observed.
- Remove the sample and cut the power to the setup.
- Repeat the same procedure by varying the input parameters.

After the sample is retrieved, it is cooled in an air tight dessicator.

3.5 RESULTS AND DISCUSSION

Figures 3 to 5 show the drying of drying characteristics of woos at 100 °C at three different fluidization velocities.

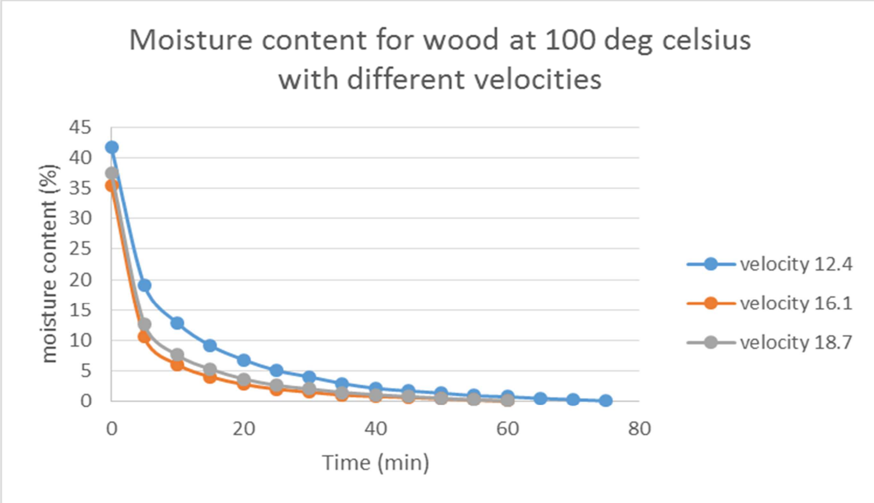

Fig.3 Moisture content for wood at 100 ℃ with different velocities

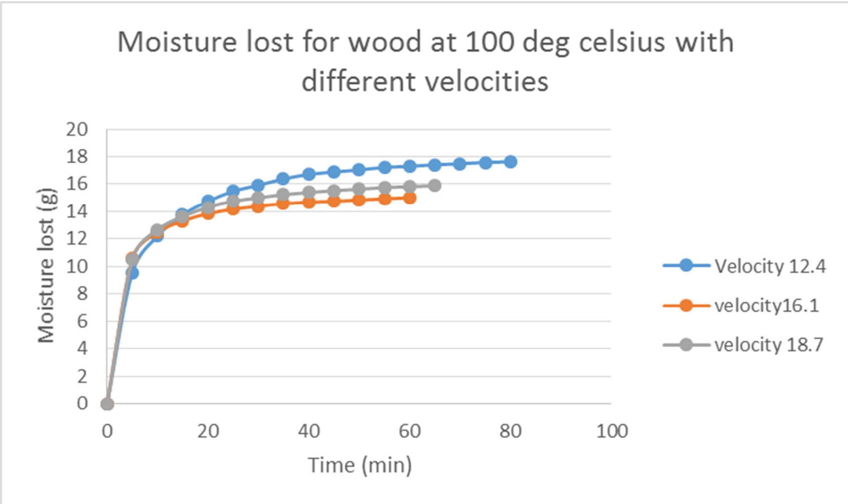

Fig: 4 Moisture lost for wood at 100℃ with different velocities

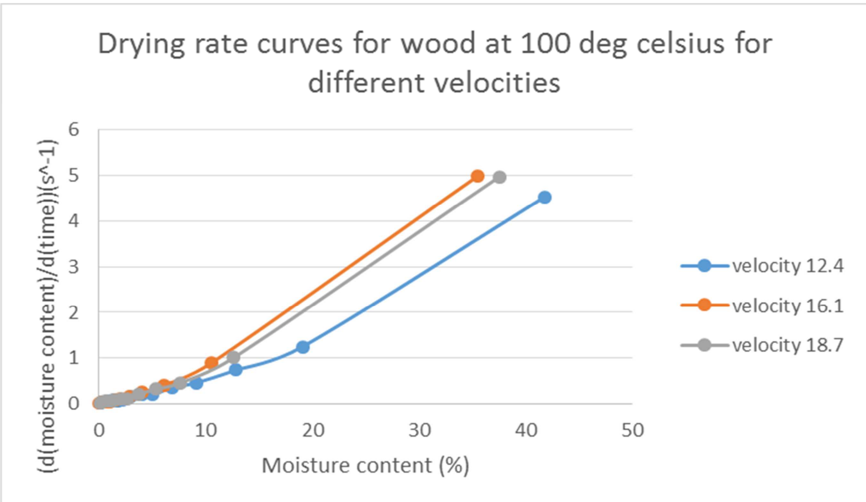

Fig.5 drying rate curves for wood at 100 ℃ for different velocities

It can be noticed that drying rate is greatest up to 7 minutes after which it drops exponentially. Drying practically ends by 40 minutes. Also noticeable is the influence of fluidization velocity. Higher the velocity, faster is the drying rate. This can be owed to the high heat transfer coefficients common to fluidized beds.

Similar trends can be observed at 115 °C bed temperature for wood. Figures 6, 7 and 8 show the drying rates for wood at 115 °C, ground nuts at 100 °C and 115 °C respectively. It can be seen that groundnuts take longer time to dry compared to wood. This is due to their low porosity compared to wood.

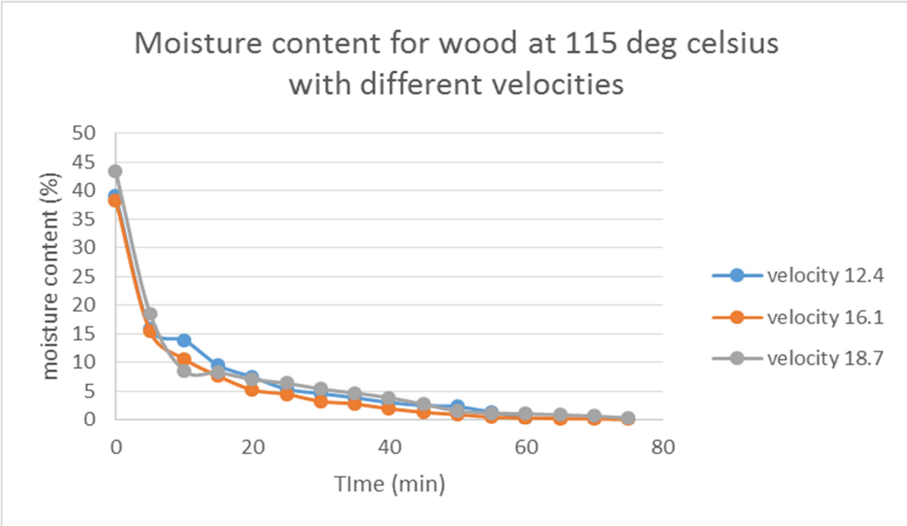

Fig.7: Moisture content for wood at 115 °C with different velocities

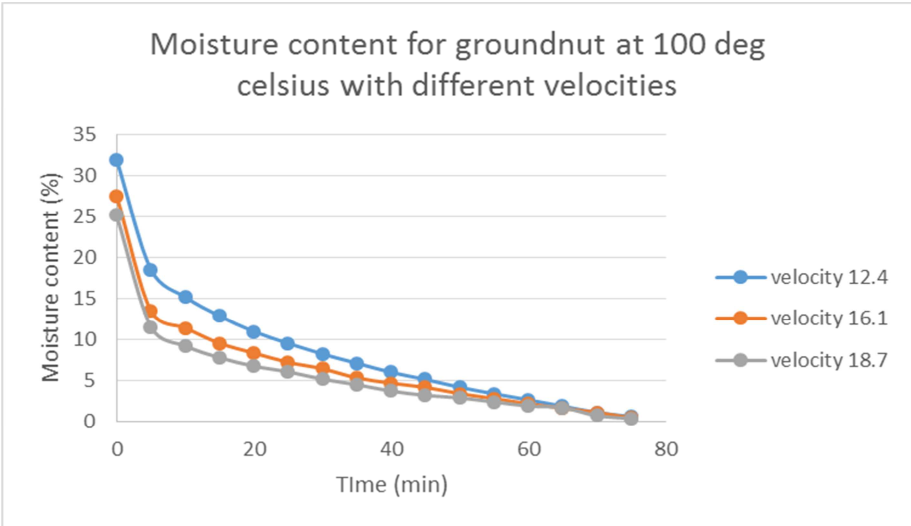

Fig.8: Moisture content for groundnut at 100 °C with different velocities

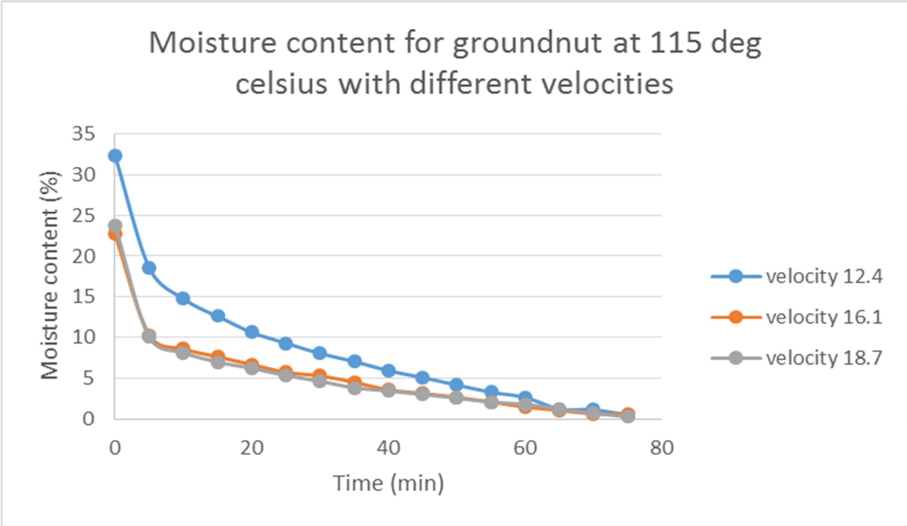

Fig.9: Moisture content for groundnut at 115 ℃ with different velocities

3.6 CONCLUSIONS

- **EFFECT OF TEMPERATURE ON DRYING**

As the temperature was increased from 100 to 110 °C, the drying of the grains was also increased (E.g. for wood when the temperature was raised from 100 to 110 °C and if velocity was taken to be 12.4m/s we have noticed that the drying time has decreased from 80 to 65 minutes as stated in the results table in appendix) Increasing drying air temperature will increase efficiency on the drying process but there is a practical limitation due to damage of the material caused by the extent of stress cracking.

- **EFFECT OF DRYING TIME**

As the drying time increases, the amount of water evaporated increased. The weight of wet samples was taken close to 50 g and when the drying time was increased the amount of moisture removed has also increased as observed from the graph plotted between drying time and moisture content which is shown in appendix.

- **EFFECT OF INITIAL MOISTURE CONTENT**

We can observe that when the initial mass of wet sample is high the moisture removed in subsequent time intervals is also high (e.g. For wood sample when initial mass were 58.56 g and 59.2 g then the moisture removed was 9.77 g and 10.24 g respectively for the next interval) and this shows the increase in the efficiency of the dryer.

- **EFFECT OF GAS VELOCITY**

When the gas velocity was increased the heating of gas had become difficult due to less time of contact and thus the moisture removed was decreased (e.g. for wood with inlet temperature 100 °C and velocities of gas were taken to be 12.4 and 16.1 m/s respectively then the moisture removed was reduced from 9.77 to 9.71 grams for the next reading). So we can say that it is better to use the air velocity as low as possible.

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