International Journal of Modern Trends in Engineering and Research
www.ijmter.com
e-ISSN No.:2349-9745, Date: 2-4 July, 2015

Heat Transfer Effects in Fluidized Bed Grain Drying Quality

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Abstract: Drying of agricultural grains, seeds is widely used to prevent biodegradation and for further processing. Fluidized bed technology is one of the most effective means for the interaction between solid and gas flow, mainly due to its good mixing and high heat and mass transfer rate. When applied to drying of non-porous moist solid particles, the water is drawn-off driven by the difference in water concentration between the solid phase and the fluidizing gas. The use of a fluidized bed dryer with a lateral air flow and mechanical activity to the drying of some selected grains was investigated. The drying rates curves in terms of moisture content versus drying time for moth beans and soybeans were obtained experimentally using a fluidized bed, the drying rates were found to be dependent on the inlet air temperature and velocity. The effects of heat and mass transfer parameters on the efficiency of fluidized bed drying have been studied to optimize the input and output conditions. The analysis was carried out using two different materials, soybean and moth beans. The objective of this study was to examine the effects of the fluidized-bed drying method on the final quality on various grains. Experimental curves of moisture content vs. drying time, as well as drying rate and the size characteristics of the products, were determined at temperatures between 40°C and 90°C, and air velocity of 0.5m/s – 1.5m/ for moisture content 45-58 % (db) to about 20-26 %(db).

Keywords: - Heat and mass transfer, biodegradation, moisture content, effective drying, dry basis.

I. INTRODUCTION

Reduction of water in food products or the processes often causes irreversible biological or chemical degradation. Since temperature is one of the major factors causing such degradation, drying at low temperature is usually preferable for achieving high product quality. Under such circumstances, improving the rate of heat transfer can provide significant benefits to the drying process. A complex transport phenomenon takes place during drying process, including unsteady-state heat and mass transfer simultaneously. The heat and moisture transfer rates are related to drying air temperature and Reynolds number as a function of velocity of the circulating drying air. In drying process therefore different mass and energy balance mechanisms are involved.

The direct contact heat and mass transfer method has been adopted in many engineering fields by using different heat transfer media [11]. In fluidized bed drying the process is carried out in a bed fluidized by the drying medium. Fluidized bed is extensively used in particulate grain drying [16]. The developments of the regime of fluidization and subsequent design modifications have made fluidized bed drying a desirable choice among other dryers. However, the efficiency of a conventional drying system is usually low. It is, therefore, desirable to improve the efficiency of the drying process.

Therefore, with increasing demand for better and higher quality products and for efficient operations, the processing technique and its control for minimizing product degradation is a current challenge for grain drying. The results showed no loss of quality due to thermal gradients if grain is exposed to temperature levels of 40ºC, 60ºC and 90ºC. This study showed that temperature alone cannot explain the observed quality degradation of moth beans and soybeans during drying. The quality of moth beans and soybeans in terms of appearance, taste, texture and colour was acceptable in comparison to the traditional method.

II. EXPERIMENTAL METHOD AND MATERIALS

2.1 Drying Method: A schematic of fluidized bed dryer system used in the present study is shown in Fig. 1 mainly consists of a fluidized bed column, electric heater and blower. The lab based fluidized bed dryer setup consists of a glass column of height 52cm. and 5.2cm diameter. The conical portion of which is filled with material to be dried. The material supported on the screen mesh held between two flanges. Air from the blower is heated in the heater box and past through the column at velocity of 1 m/s by adjusting flow varying the cross section opening by operating needle valve. And air flow velocity is measured by the hot wire anemometer. Orifice with differential manometer is provided to the measure the air flow rate. The flow rate can be adjusted by needle valve provided for air supply to the column. Sensors are given at different positions to measure the temperature of inlet and outlet of air flow through drying section of fluidized bed dryer.

During fluidization the particles are circulated within the fluidized bed. This circulation has a direct bearing on the heat transfer properties of gas solid fluidized bed system. Fluidized beds have been used for heat exchange in both physical operations and chemical process because of rapid transport. Also, because of mixing uniform temperature throughout the bed can be maintained. Calculations of drying curve from the record of moisture contain of the drying medium.

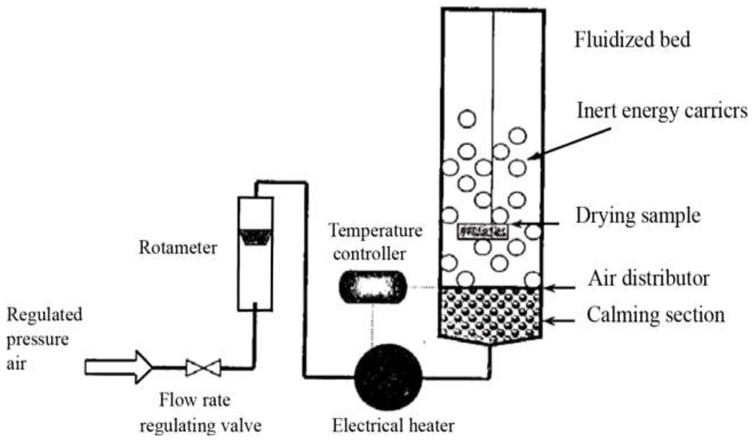

Fig. 1: Schematic diagram of Fluidized Bed Drying

2.2 Fluidization: When a fluid enters at sufficient velocity from the bottom and passes up through the particles, the particles are pushed upward and the bed expands and becomes fluidized. During fluidization the particles are circulated within the fluidized bed. This circulation has a direct bearing on the heat transfer properties of gas solid fluidized bed system. Fluidized beds have been used for heat exchange in both physical operations and chemical process because of rapid transport. Fluidized bed drying is a process of contact between the two phases. The solid phase, under fluidization conditions, assumes a "fluid like" state. When drying air is passed upward through a layer of wet material, as shown in Fig. 2, the gas will pass at low flow rates through the fixed bed of particles. As the gas velocity is increased, the pressure drop across the particle layer will increase until all particles are suspended in the upward-flowing drying air; the gas velocity at this point is called the minimum fluidization velocity, U_{mf} .

When the drying air velocity increased further above Umf, the gas will pass through the particle layer as bubbles. At still higher gas velocities, a point is reached at which the drag forces are increased to a degree that the particles become entrained within the gas stream and are carried from the fluid bed as a pneumatic transport. A comprehensive mathematical model to simulate heat and mass transfer in bubbling fluidized bed has been described in the previous studies [7, 8].

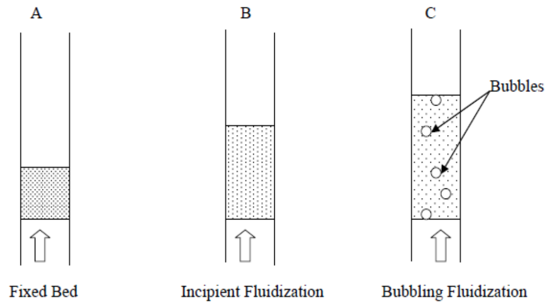

Fig.2: Fluidization processes

2.2 Experimentation: The soaked moth beans and soybeans in water are used for experimentation. The flow rate maintained which should be sufficient to fluidize the material. Dry it completely and weight it again and hence recorded the percentage moisture present. Repeated the steps for constant air flow rate at the hot air temperature 40°C, 60°C, and 90°C. Observations were recorded as in the weights recorded at 5-10 min. intervals and drying curve and drying rate is obtained are as in fig. 3 and 4.

2.4 Effect of heat and mass transfer parameter: Heat transfer in gas-fluidized bed can occur by conduction, convection, and radiation depending on the operating conditions. The contribution of the respective modes of heat transfer to the coefficient of heat transfer depends on particle classification, flow condition, fluidization regimes, and type of distributor, operating temperature, and pressure. Heat transfer between a single particle and gas phase can be defined by the conventional equation of heat transfer:

$$q = h_p A_p \, (T_p - T_g)$$

Where, q is the rate of heat transfer (W), $h_p$is the heat transfer coefficient (W/ (m²K)), A_p is the surface area of a single particle (m²), $T_p$is the temperature of the particle (°K), and T_g is the temperature of gas (°K). [17]

Since the initial moisture content of grain (M_o) used in the experiment at various inlet air conditions is different, comparison of drying time and efficiency in terms of absolute moisture content may be misleading. Therefore, the non-dimensional moisture content MR is used for analyzing the data.

$$MR = \frac{M_t - M_e}{M_o - M_e}$$

Where, M_t and M_e are the moisture content of grain as a particular time and equilibrium respectively.

It was observed that as a general trend, the results obtained for both materials are similar. Energy efficiency was found to be higher. Furthermore, at the beginning of the drying process, energy efficiencies were observed to be higher than at the final stage. The energy efficiency of the fluidized bed dryer column was found to be very low at the end of the drying process.

III. RESULTS AND DISCUSSION

Experimental data showing the effect of temperature, flow rate of the heating medium and solids holdup are shown as plots of moisture content versus time, in Fig.3. The rate of drying is higher at the early stage of drying while the moisture content was high and reduces as the moisture content decreases. Fig.4 shows the effect of temperature of the heating medium at two different solids holdup. An increase in temperature of the heating medium increases the drying rate and it can be attributed to the higher bed temperature of particles in the bed, which increases the intra particle moisture diffusion to the surface of the solid resulting in a higher drying rate.

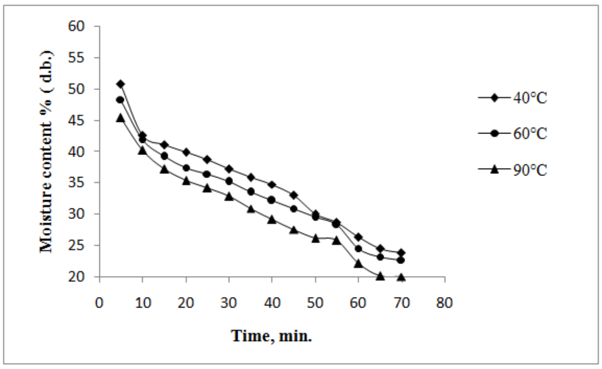

Fig. 3: Drying curve in FBD

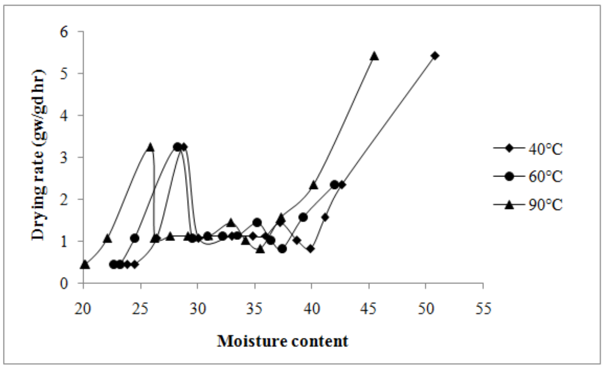

Fig.4: Drying rate in FBD

Looking at the drying curve, as the rate of drying reduces from start until the end of drying period one would expect the entire operation to be an internal mass transfer controlled and would expect a negligible effect of air flow rate on the drying rate. However, a continuous recording of the bed temperature indicated that the effective bed temperature increased with flow rate of the heating medium, which increases the moisture diffusion rate and thereby results in higher drying rate. Repeat experiments were conducted to eliminate the effect of experimental error on assessing.

IV. CONCLUSION

The grains were dried from the initial moisture content in the range of 45-58%db to about 20-26%db. However, there were several runs in this study in which grains were dried below the moisture content of 30%db. This was because additional data were required or needed for a better understanding of the drying characteristics of grains in a fluidised bed dryer. Drying performance in the fluidized bed dryer was better than the other methods of drying used for drying moth beans and soybeans. Colour was retained by the dried moth beans with change in the texture by contracting the area of the dried product. Some textural cracks appear on the moth beans drying in the fluidized bed dryer at higher temperature drying.

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