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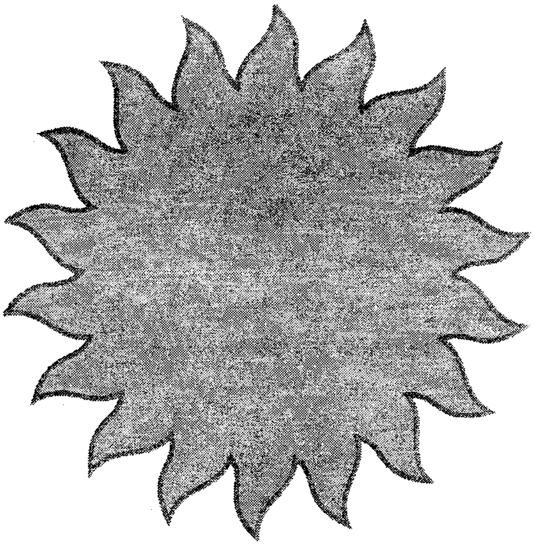

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FLUIDIZED BED DRYING OF NUTS

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ABSTRACT

Fluidized bed drying operation was performed for the nuts. In the experiments, laboratory scaled fluidized bed was used. Drying characteristics of the nuts in the fluidized bed were observed with two different temperature and velocity of the air. Effects of the velocity and temperature of the air on drying process were investigated. A good agreement between the experimental results and same works in the literature was obtained. The goal of this work is to present the experimental results on the drying characteristics of the nut.

INTRODUCTION

Advantages of fluidized bed drying system over conventional drying methods have motivated extensive applications of this system in food, chemical, pharmaceutical and mineral industries. These advantages are; uniform moisture distribution throughout the bed, high heat and mass transfer rates between the gas and particles, good mixing and ease in transport and handling of particles. Although there are industrial developments and applications, the theoretical investigations have not yet been well developed and much research is needed to increase our understanding on the effect of fluidization phenomena on drying processes.

Chandran et al. (1990) developed kinetic model for the drying of solids in fluidized beds, assuming a falling rate period following a constant rate period. They obtained the experimental data using batch and continuous single and spiral fluidized beds. Their results are satisfactorily matched with the assumed drying kinetics and the residence time distribution of solids appropriate for the type of dryer. Abid et al. (1990) investigated an experimental and theoretical analysis of the mechanisms of heat and mass transfer during the drying of corn grains in a fluidized bed. Their theoretical analysis of the internal mechanisms of heat and mass transfer has been carried out starting from the model of Luikov which is based on the irreversible thermodynamics. This model takes into account the transfer of water by diffusion under the influence of a gradient of the concentration in moisture and by thermodiffusion under the influence of a temperature gradient. Thomas and Varma (1992) experimentally investigated batch and continuous fluidized bed drying of granular cellular materials at different temperatures and flow rates of the heating medium, particle size and mass of solids.

Dimattia et al. (1996) performed batch drying of red spring wheat in a fluidized bed. They investigated effect of bed height, gas velocity, initial moisture content and air temperature on drying rate. Dimattia et al. (1997) investigated slugging characteristics of Group D particles in fluidized beds. Karatas and Battalbey (1991) studied on the determination of moisture diffusivity of pistachio nut meat during drying. Puiggali et al. (1987) developed and used an equation to describe the kinetics of air drying of hazelnuts. They proposed the layer drying equation for drying of hazelnuts. They used it with a fixed deep-bed drier model to obtain a comparison with experimental results. Bhagya and Srinivasan (1989) investigated the effect of different methods of drying on the functional properties of enzyme treated groundnut flour. They determined certain functional properties of enzyme treated groundnut flour dried by freeze drying, spray drying, vacuum shelf drying and drum drying. Liang et al. (1989) developed a macadamia nut curing system for improving kernel recovery. Moreira and Arkema (1989) developed a moisture desorption model for nonpareil almonds. They determined the drying characteristics of individual almonds and almond parts (hull, shell, nut) at 41.3 and 45.9 °C and 38-8% relative humidity. Erbil (1997) studied on the prediction of the fountain heights in fine particle spouted bed systems. She proposed a new empirical correlations to predict the fountain heights in spouted bed systems operating with fine particles.

Ersoy et al. (1997) studied on solids holdup and particle velocity measurements in a circulating fluidized bed with secondary air injection. Wang (1993) developed a mathematical model for the drying process in a fixed bed dryer. He modeled the drying process in a fixed bed dryer in terms of balance equations masses and energies that result in a hyperbolic system of conservation laws with a source term. He solved this system numerically by an operator splitting technique based on Strang's algorithm. Hajidavalloo and Hamdullahpur (1998) proposed a mathematical model of simultaneous heat and mass transfer in fluidized bed drying of large particles. They employed a set of couples non-lineer partial differential equations to accurately model the process without using adjustable parameters. They used a three phase model representing a bubble phase, interstatial gas phase and solid phase to describe the thermal and hydrodynamic characteristics of the bed.

In this study, drying characteristics of the nuts have been investigated in the fluidized bed. Drying process was performed with two different temperature and velocity of the air in the experiments.

EXPERIMENTAL STUDY

Physical properties of materials

Nut was used in the study as a drying material. It is approximately spherical in shape. Nuts were assumed to be a spherical with an average diameter of 16mm. They were seperated with two sieve which have 15mm and 17mm hole diameter. Initial moisture content of nuts are in the range of 21-26% dry basis. Other properties of nut can be found in Table 1.

Table 1. Physical properties of nut.

Name	Value	Unit
d_p	16	mm
c_p	1650	J/kg K
ρ_p	795	kg/m^3

Density of nut was measured in this study.

Experimental setup

To investigate the drying characteristics of the nut, laboratory scale fluidized bed is designed and constructed. It is shown in Fig.1 The bed column was made of Plexiglass with 196mm inner diameter, 1000 mm height and 2mm wall thickness. A perforated distributor plate 2mm thickness and 15mm holes was used to obtain uniform distribution of the fluidizing air. The air heater consist of 4 stripped electric elements have 2000 watt total power. The air was provided by centrifugal blower. The temperature distribution through the bed was measured by thermometer (Testo 905-T1, Type K thermocouple) at different heights above the distributor plate. Pressure difference between two side of distributor plate and distributor plate and fluidized bed height was measured with electronic pressure cell (Testo 505-P1, mbar, mmH_2O units). Air velocity was measured and determined with pitot tube (chromium-plated brass, 350mm length, 7mm diameter) and electronic pressure cell. Inlet and outlet humidity of the air were measured with using humidity measurement stick (Testo 605-H1, 125mm length, 12mm diameter, 5 to 95 %RH, 0.1%RH resolution).

The moisture content of particle was observed with using Sartorius moisture analyzer. Moisture analysis is based on infrared drying. In this process, moisture is removed from the sample by heating. The difference between the initial weight and the final weight yields the moisture content of a sample.

Before each experiment, the unit was run in the absence of particle for about 2 hours to reach thermal steady state. After the bed reached the required temperature and stabilized, the air supply and power to heater was turned off and the material was charged into the bed as quickly as possible. The air supply and heater power were then reinstated.

All experiments were conducted under batch fluidization. During the experiments temperature distribution through the bed and bed pressure drop were measured. As fluidization continued, solid samples were removed from the column at different times and were analyzed for their moisture content.

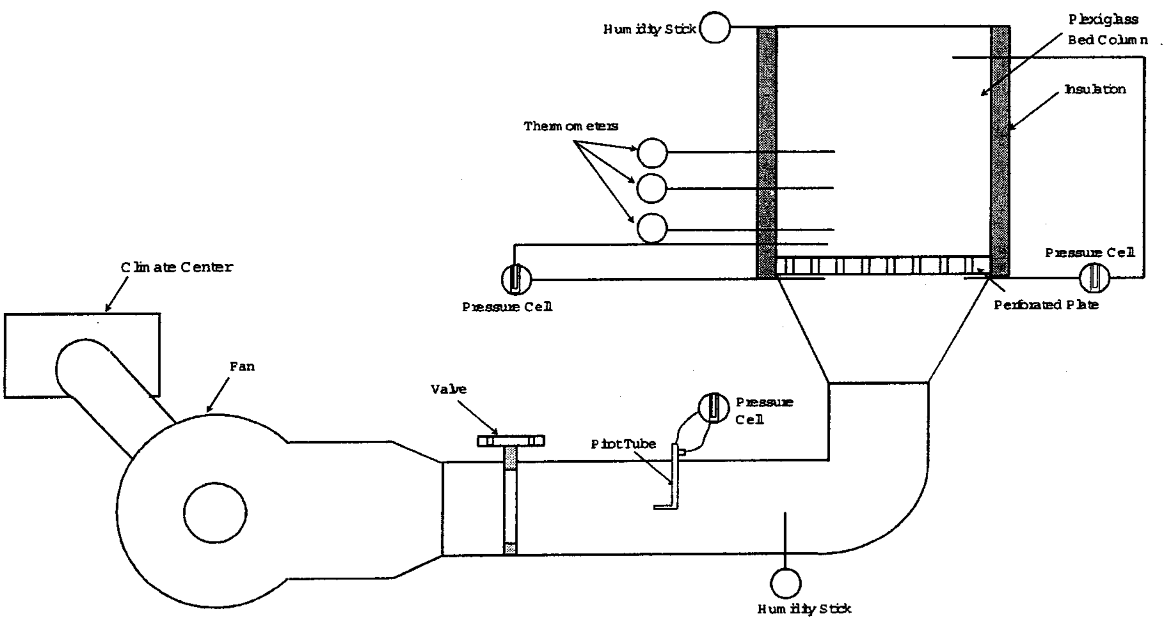

Figure 1. Schematic diagram of experimental setup.

Minimum fluidization velocity

Fig. 3 shows the bed pressure drop versus gas velocity in the bed column. At the start of fluidization, not all particles are fluidized due to existence of the cohesive force in the bed. Usually bottom section of the bed or some other parts is partially fluidized. Thus, the bed pressure drop is slightly less than the pressure drop equivalent to the weight of bed material. By increasing the gas velocity further, the drag force exerted on the particles increases and this can break apart more contact points between particles and bring them to fluidized state. Consequently, the pressure drop increase with increasing the gas velocity as more particles require to be suspended. At a certain velocity, all particles will eventually be suspended and full fluidization will take place. At this point, the pressure drop would be higher than the weight of bed, because of the effect of the cohesive force.

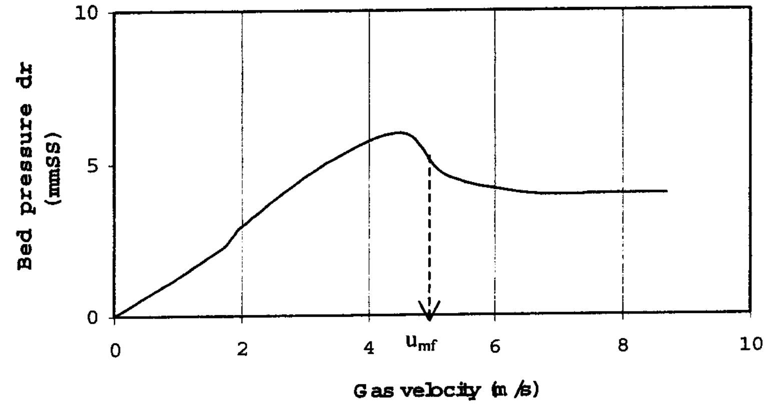

Figure 3. Minimum fluidization velocity of nut.

EXPERİMENTAL RESULTS

In the experiments, two different velocity and temperature of the air was used. Temperature distribution through the bed versus time can be seen in fig. 4.

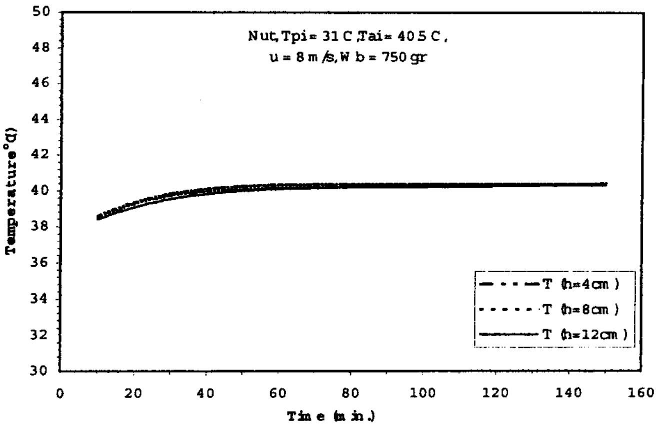

Figure 4. Temperature time profile for a drying run of nut.

Fig 4 shows the temperature gradient within the bed during drying run. At the various points, temperature within the bed was relatively uniform after the first 40 min. of drying.

At the beginning of drying, the gradient of temperature is important and after a while the temperature distribution in the bed becomes nearly uniform. Since in the initial stage the drying rate is very high, it is important to take into account the temperature gradient inside the bed for accurate modeling of the drying process. As shown in fig. 4, increasing the bed height, reducing the temperature of the air in the bed column for the same period of drying time.

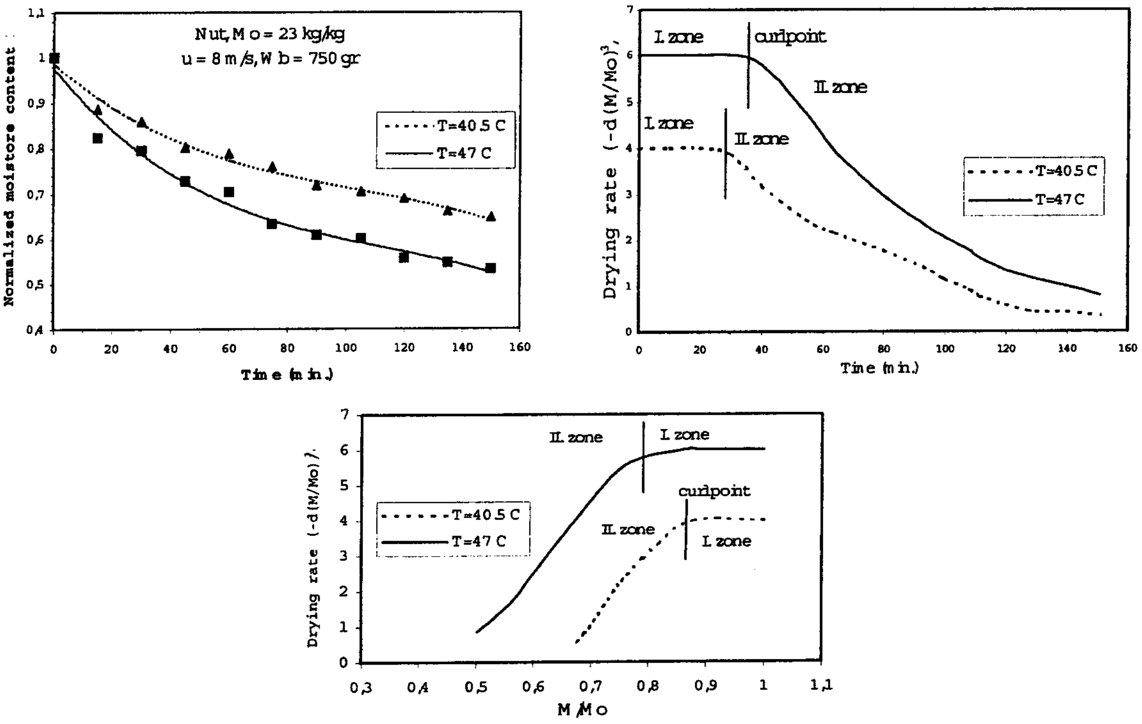

Figure 5abc. Effect of gas temperature on the drying of nut.

The figures 5-6 show that effect of the temperature of the air and velocity of the air on the kinetics of drying process, respectively. It is seen from the figures that the batch drying of solids exhibits constant rate and falling rate period whose relative magnitudes depend on the system conditions. The drying rate in the constant rate period is enhanced with an increase in temperature. The presence of constant rate period indicates whether the controlling resistance is limited to external diffusion or to the diffusion of moisture through a layer of crest at the surface. Temperature influences little in a diffusion controlled process while its effect is slightly higher when external diffusion controls. Rate of drying is affected by the superficial velocity of the drying medium only when external diffusion is controlling.

The prediction of the range of moisture content over which the constant rate period prevails, is difficult. This range depends on the rate at which moisture is supplied to the surface vis a vis its evaporation from the surface. The mechanism of this supply may be one of several; but, irrespective of the transfer mechanism, the critical moisture content depends on the heating medium conditions, the properties of the material being dried and the hold up of the solids.

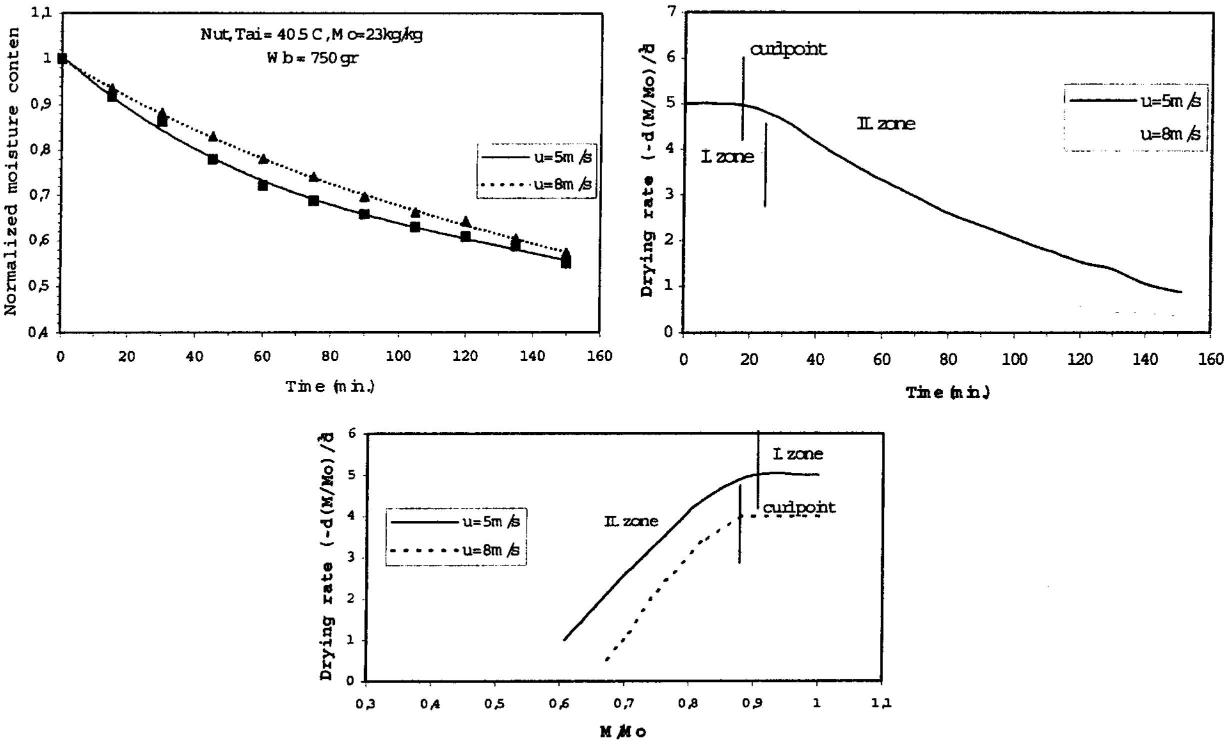

Figure 6abc. Effect of gas velocity on the drying of nut.

Fig. 6 shows the effect of gas velocity on the normalized moisture content. In the literature, from the several papers, it is understood that velocity of the air has not played an important role on the drying process. But the drying rate is slightly enhanced by an increase in velocity of the air. On the other hand, as shown in fig. 6, increasing the velocity of the air was provided to decrease the drying rate. Because the gas velocity increased and slugging regime was entered. Dimattia et al. (1997) found a correlation based on the data to predict the minimum slugging velocity.

$$u_{ms}=u_{mf}\,(1.0551-2.283\,\log\Psi_s) \qquad (1)$$

According to this correlation, minimum slugging velocity of the nut is up to 6.3m/s. Therefore, in fig. 6, drying rate was reduced due to increment of the velocity of the air.

CONCLUSION

Drying characteristics of the nut in the fluidized bed were observed with two different temperature and the velocity of the air. Temperature time profile for drying of nut through the bed and effect of gas temperature and velocity on the drying of nut were investigated. Temperature has an important effect on the kinetics of drying, but velocity of the air has not played an important role on drying rate. Increasing the temperature allows rate of drying to be increased. Drying rate is slightly enhanced by an increase in velocity. But in this work, increasing the velocity of the air was provided to decrease the drying rate. Because the gas velocity increased and slugging regime was entered.

NOMENCLATURE

ρ_p = Density of the particle, kg/m^3
c_p = Specific heat of the particle, j/kg K
M = Moisture content of the particle (kg moisture/kg dry solid)
T_{ai} = Initial temperature of the air, °C
T_{pi} = Initial temperature of the particle, °C
u_{mf} = Minimum fluidization velocity, m/s
u_{ms} = Minimum slugging velocity, m/s
Ψ_s= Sphericity of the particle, -

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