Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.2924

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **5 (4):** 204-211 (2017)

Research Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Design and Construction of VFBD and Drying Kinetics of Muskmelon Seeds

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Received: 27.04.2017 | Revised: 8.05.2017 | Accepted: 10.05.2017

ABSTRACT

The main objective of Muskmelon seed drying is the reduction of its moisture content to a safe level and to overcome the main problem associated with the drying of muskmelon seeds. The problem encountered during convention drying is the lump formation causing uneven and under-drying of muskmelon seeds, therefore vibro-fluidized bed dryer (VFBD) was designed with better heat and mass transfer and shorter drying time. Muskmelon seeds were dried in the VFBD at 60°C, 70°C and 80°C and drying characteristics were studied. VFBD is having capacity 7-8 kg/batch, air flow rate of 700 m^3/h, bed velocity of 1.9 m/s. The frequency of the vibrations was varied between 6 to 11 Hz and the amplitude of vibrations was 10 mm. Average moisture content of seeds was reduced from 100% dry basis db to 7% db. Based on experiments it was found that time required to dry the seeds is considerably reduced when drying at higher temperatures i.e., at 80°C for 25 minutes.

Key words: *Drying, Vibro-fluidized Bed Dryer, Moisture Content, Fluidization, Drying Rate.*

INTRODUCTION

Drying may be viewed as either a preservation technique or as a manufacturing step and in many cases performs both functions simultaneously[4]. As food preservation method, drying implies reducing the moisture content to a level where the growth of microorganisms is inhibited or where the rate of chemical deterioration of foods is minimized. Different driers are used for drying different materials[3].

The choice of dryer is also governed by the quantity produced and the quality of the dried product. Vibro-Fluidized bed drying can prove to be highly beneficial in this regard. It can be viewed as good hybrid drying system[2].

Cite this article: Gulzar, S., Deshmukh, G., Birwal, P., Patel, S.S. and Singham, P., Design and Construction of VFBD and Drying Kinetics of Muskmelon Seeds, *Int. J. Pure App. Biosci.* **5(4):** 204-211 (2017). doi: http://dx.doi.org/10.18782/2320-7051.2924

When Vibro-Fluidized Bed Dryers (VFBDs) are compared with conventional ones, the former show a number of advantages, such as: better mixing, reduction of air flow requirements, and smaller pressure drops, in addition to the ability to fluidize cohesive and viscous materials. Research on Vibro-Fluidized Bed Dryers is extensive, summarized basically as studies on the pressure drop through the bed and the minimum vibro-fluidization rate. There are several bed characteristics like height of bed and shape and size of the particles and mathematical descriptions in case of VFBDs. Different models such as Single Bed Model, Ryzhkov and Baskokov Model and Gutam Model have been introduced to understand the gas velocity of the bed in different consideration[1].

Cantaloupe or Muskmelon (Indian name) refers to a variety of Cucumis melo, a species in the family Cucurbitaceae and its seed is generally a grayish white hard shell with a white inner kernel, which is soft and oval in shape. These seeds are a good source of potassium, vitamin A, vitamin C, folate, zinc, manganese, magnesium, iron, copper, calcium, vitamin B3 and vitamin B2, antioxidants, rich in protein, omega-3 fatty acids, fats and other nutrients. The melon seeds are used in baking, dressing of bread cake, confectionery, supari, sweets, refreshing drinks, snack foods and can also be directly consumed after roasting. Drying parameters of moisture diffusivity and energy are vitally important in modelling and optimizing of the seed dryer system. Soponronnarit *et al*.[5] have designed several prototype fluidised bed paddy dryers such as the cross-flow fluidized bed dryer. The earliest commercial use of Vibro-Fluidised Bed Dryers (VFBDs) dates back to 1938 for drying of molybdenum ore by Allis-Chalmere.

This research summarized operating conditions of VFBD based on bed characteristics, heat transfer and minimum fluidization velocity also effects of different time-temperature profiles on the drying characteristics of muskmelon seeds.

MATERIAL AND METHODS

Muskmelons (Cucumis melo) were bought from a local market in Sonepat district of Haryana. The true density of seeds was measured by liquid pycnometer method using water with density of 0.9939 kg/m^3 at 25°C.

Designing and fabrication of dryer:

Designing of the dryer started with making of the designs in the SolidWorks 2012. Plenum chamber of the dryer is meant for inlet and distribution of the hot air inside the dryer. The internal diameter of the plenum chamber is 350 mm and a height of 250 mm. The material of construction of the entire drying chamber and plenum chamber is stainless steel (SS-304).

The dryer was having plenum chamber with outer diameter 390 mm and a flange which acted as a support to distributor plate. The flange consisted of 6 holes for full thread hex bolts. A distributor plate on which whole drying takes place was placed between the plenum chamber and drying chamber which provides the base for the drying material. The distributor plate was 1 mm thick and made of SS-312 with holes diameter of 2 mm and 4 mm pitch. The size of the holes varies as per the drying requirements. The type of distributor plate holes used in this study is circular. The main drying chamber lies above the distributor plate. It was made of SS-304. The length of the drying chamber is 400mm and an internal diameter is 350 mm. The drying chamber was provided with a window with a transparent acrylic plate fitted to visually monitor the drying process inside the drying chamber. The material is fed in to the dryer and taken out through window. There was exhaust duct with diameter of 120 mm is provided at the top of the drying chamber. The thickness of the material (SS-304) used in the entire setup is 2 mm. The total volume of the drying chamber calculated is 0.0384 m^3 but only 30% of the total volume is used for efficient drying process. The drying chamber was supported on the main frame made from angle bars of mild steel of 6mm thickness. The dimensions of the main frame are length 2 ft., breadth 2 ft., and height 2.5 ft.

The main frame has 4 springs which facilitates the vibrations in the drying chamber.

The DC motor for causing vibrations is also attached to the base of the main frame. The length of each spring is 95 mm. The hot air blow through hot air blower fitted with a motor of 2 hp capacity. To heat the air entering in the blower a preheater with 2000 W capacity provided at the inlet. Another heater of 3000 W capacity was fitted at the outlet of the blower to heat the air to the desired temperature. The combined set of heaters raised the temperature of the system to 120°C. Although the dryer was operated at a lower temperature but there is a provision to use it at a relatively higher temperature. A ducting pipe made of polyurethane transfer the hot air to the plenum chamber. This pipe can withstand the temperatures up to 150°C.The temperature control is provided by the PID controller with range from 30°C to 600°C. The vibrations to the drying chamber are provided by the DC motor of 1 hp capacity.

Table 1: Different Parts of Self -designed VFBD along with their Specifications.

Part	Specifications
VFBD A. Drying chamber	Volume 0.0384 m^3 Capacity 10-15 kg per drying cycle
B. Hot air blower	Air Flow Rate 650-670 m^3/hr Heater A 2000 W Heater B 3000 W Motor Capacity 2 hp with 2800 rpm
C. PID controller	Max. temp 600°C, Min. temp 30°C
D. DC motor	Motor Capacity 1 hp with 1500 rpm
E. DC drive	Voltage regulation from 0 to 270V
F. Thermocouple	32 to 1400°F ±4.0°F or 0.75%

The motor had an eccentric cam with a predefined eccentricity, which converted the circular motion of the motor to the linear motion, required for the vibrations, using a tie-rod which was attached to the bottom of the plenum chamber. The amplitude of the vibrations could be adjusted by changing the position of tie-rod with respect to cam. The amplitude of vibrations during the trials was kept constant at 10 mm. The frequency of the vibrations was also adjusted by changing the voltage supplied to the motor using the DC drive. The frequency was varied between 6 Hz to 11 Hz. The moisture content was calculated after 24 hours for each sample. Specifications are in table 1.

RESULTS AND DISCUSSION

Design and Fabrication

VFBD was successfully designed using the 2D and 3D drawings in SolidWorks 2012 software. The dryer was fabricated from Krit Mann fabricators in Delhi. The total cost of the dryer was about Rs. 70,000/-. Some parts of the dryer like thermocouple, inlet duct and preheater were installed later during trials. An overall experimental setup of Vibro-Fluidized Dryer is shown in Fig. 1. The schematic diagram of VFBD is shown in Fig. 2 below which include preheater, hot air blower, heater, duct for hot air, plenum chamber, distributor plate, drying chamber, motor for vibrations, shaft for vibrations, main frame, spring and exhaust Duct.

Vibrational Frequency

The vibrational frequency was calculated by using the linear relationship between rpm and voltage set in the DC drive.

Using the relation 1 rpm = 0.01666 Hz

The DC drive was operated at 40V, 50V and 60V

Full scale reading of DC drive = 270V

Maximum rpm of motor = 2800 rpm

Frequency of the vibrations at 40V = 2800/270 x 40 x 0.01666 = 6.9 Hz

Frequency of the vibrations at 50V = 2800/270 x 50 x 0.01666 = 8.6 Hz

Frequency of the vibrations at 60V = 2800/270 x 60 x 0.01666 = 10.3 Hz

Drying Kinetics

The dryer was operated at the air velocity of 1.9 m/s and air flow rate ranging between 650-670 m^3/hr. The frequency of the vibrations was varied between 6 to 11 Hz and the amplitude of vibrations was kept constant at 10mm. The results shown with varying the temperature of the drying air at T= 60℃, T= 70℃ and T= 80℃ are depicted in the drying curves. The increase in temperature gets about rise in evaporation rate and effective mass diffusivity which result in higher drying rate. The same results were achieved by plotting moisture ratio versus time. Continuous decrease in moisture ratio indicates that diffusion has governed the internal mass transfer. Therefore, moisture ratio decreased in specific time with increasing at inlet air temperature. Results shown in the plot between moisture content and drying rate depict a sharp rise in the drying in the first 10 minutes which corresponds to the free falling rate of drying and as the moisture was reduced below 30% the rate of drying was almost constant followed by the decrease in the drying rate below 10%.

Muskmelon seeds were dried in the VFBD at 60°C, 70°C and 80°C and the samples were taken out after every five minutes. The relationship between moisture content and time at 60°C, 70°C and 80°C is shown in the Fig. 3, 4, 5 respectively.

The amount of water removed from muskmelon seeds after drying at 60°C, 70°C and 80°C along with time taken and the drying rate was calculated. The relationship between the moisture content and drying rate is shown in Fig. 6. The moisture ratio at five minutes intervals for a total time of 30 minutes was also calculated at 60°C, 70°C and 80°C.

$$MR = \frac{(Mt - Me)}{(Mi - Me)}$$

where; MR = Moisture Ratio

M_t = Moisture content of the sample at any time.

M_e = Equilibrium moisture content of the sample.

M_i = Initial moisture content of the sample.

The values of the equilibrium moisture content, M_e are relatively small compared to M and M_o. Thus, the Moisture Ratio can be calculated as MR = M_t / M_i. The relationship between moisture ratio and time is shown in Fig. 7

Fig. 1: Experimental setup of Vibro-Fluidized Bed Dryer

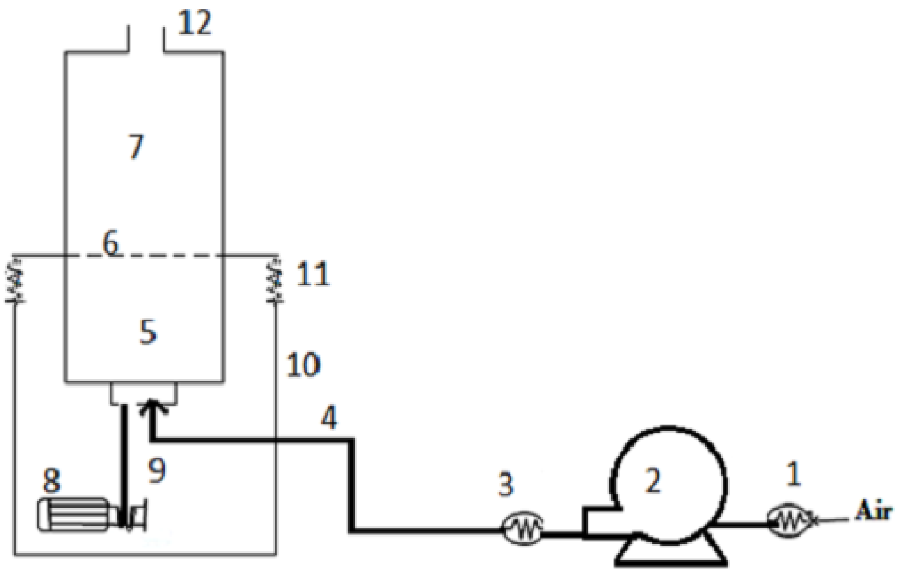

Fig. 2: Schematic Diagram of the Vibro-Fluidized Bed Dryer, (1) Preheater, (2) Hot Air Blower, (3) Heater, (4) Duct for Hot Air, (5) Plenum Chamber, (6) Distributor Plate, (7), Drying Chamber, (8) Motor for Vibrations, (9) Shaft for Vibrations, (10) Main Frame, (11) Spring, (12) Exhaust Duct

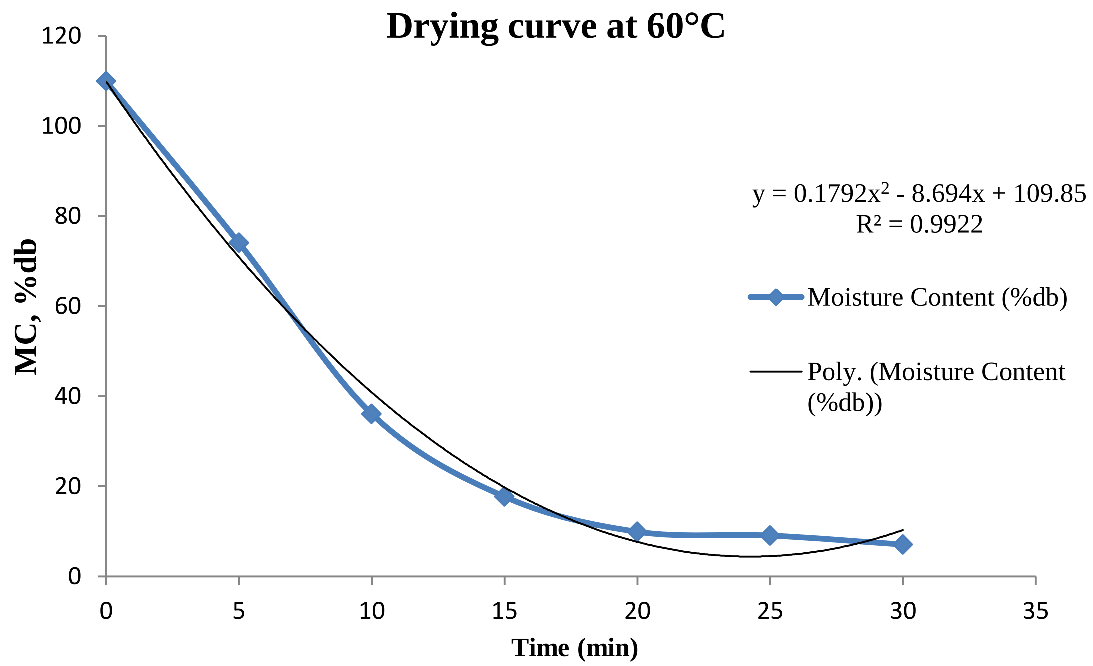

Fig. 3: Drying Curve of Muskmelon Seeds after Drying at 60°C.

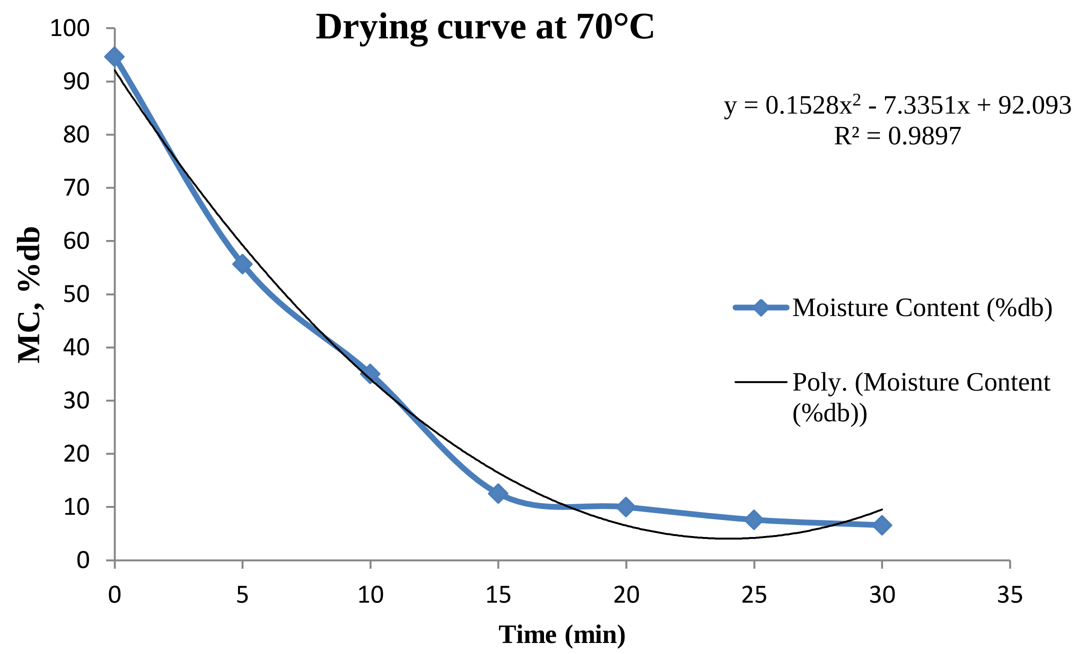

Fig. 4: Drying Curve of Muskmelon Seeds after Drying at 70°C

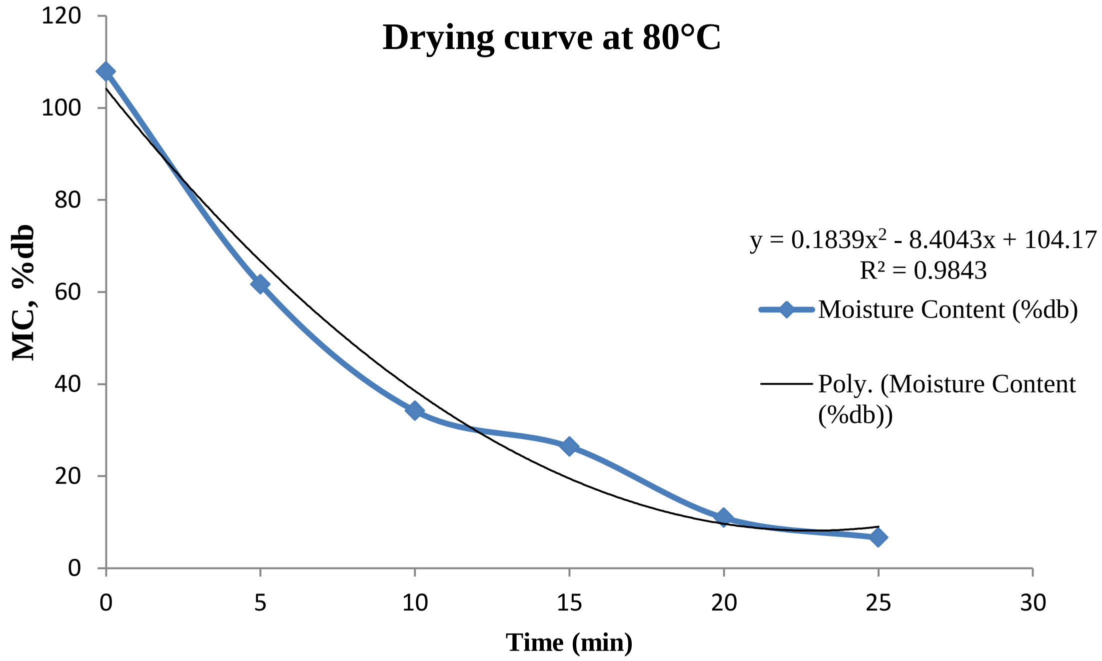

Fig. 5: Drying Curve of Muskmelon Seeds after Drying at 80°C

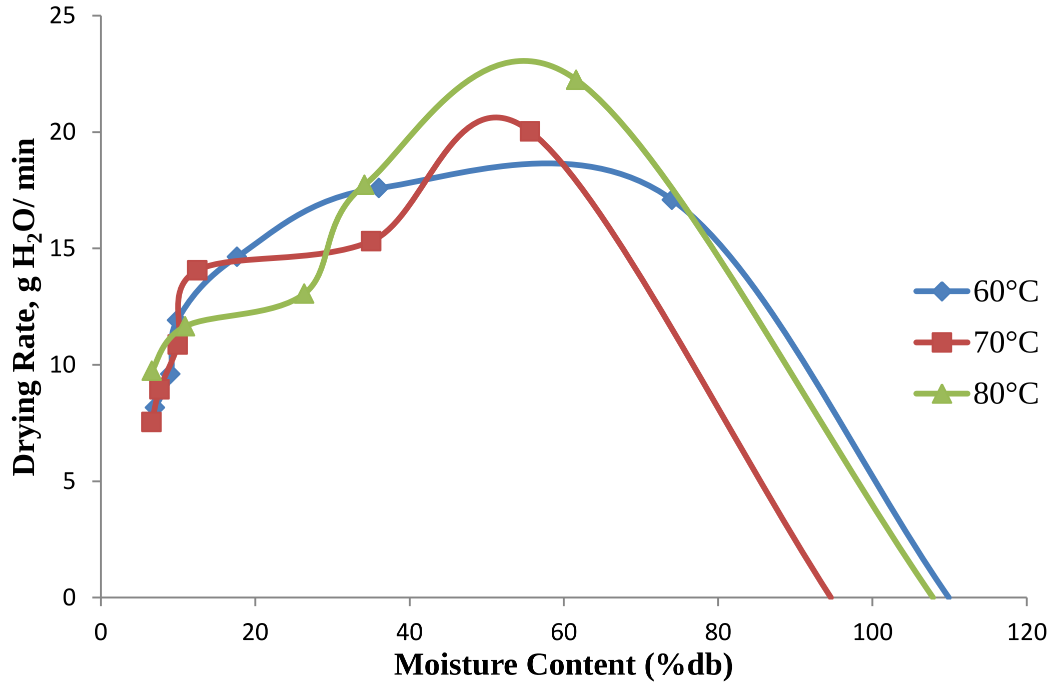

Fig. 6: Moisture Content vs. Drying Rate Curve

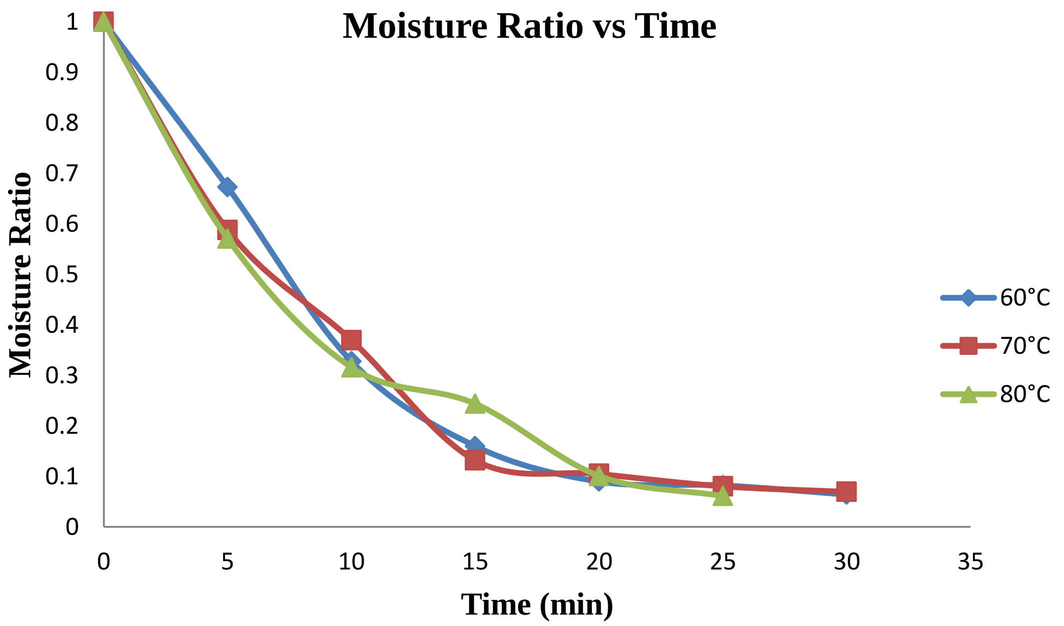

Fig. 7: Moisture Ratio vs. Time curve

CONCLUSION

After constructing the dryer and conducting the experiments for drying of Muskmelon seeds it was found that this type of vibro-fluidized bed dryer is best suited for drying of Muskmelon seeds since these seeds have highly viscous nature and are inseparable from each other. The fluidization velocity was just found to be sufficient to fluidize the material. VFBD is best suited for drying of muskmelon seeds due to their viscous and cohesive nature. Fluidization was slow at the beginning of the drying process which indicates towards the higher initial moisture content of the seeds. The drying curves drawn at different temperatures clearly depict the free falling and constant rate drying.

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