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Application of RSM in Fluidized Bed Drying of Beetroot (*Beta Vulgaris L.*)

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Abstract: *In the present work, an attempt has been made to study the effect of inlet air temperature and inlet air velocity on the drying characteristics of (*Beta vulgaris *L.) pieces in fluidized bed drying (FBD) system. The inlet air temperatures selected were 60°C, 67.50°C and 75°C and inlet air velocities were 9 m/s, 10.50 m/s and 12 m/s. Moisture content and outlet air humidity was measured at 5 minutes interval. It was observed that the beetroot samples obtained from the FBD system had lower final moisture content. The beetroot vegetables were sliced into size (LxWxT) was 7 mm x 7 mm x 1 mm respectively. After slicing and cutting, for each experiment, 500 g accurately weighed samples were taken in fluidized bed drying chamber. The results were analyzed by using Response Surface Methodology (RSM). Face Centered Central (FCC) composite design of RSM was applied for optimum drying conditions (i.e. inlet air temperature and inlet air velocity) for individual parameters (variables and responses), and overall optimization was also performed, taking into account the goals of both the responses.*

Keywords: *Fluidized bed drying, Beetroots, Beta vulgaris L., Chukander and RSM.*

1. INTRODUCTION

Beetroot is a tuber crop which is used for drying in fluidized bed dryer. Drying is the excellent way to preserve foods is drying that is an oldest method of preserving high moisture foods. With the several advantages, drying can add variety to meals and provide delicious and nutritious foods. Among them, dried foods take much less storage space than canned or frozen foods. Drying, however, is a difficult and complicated food processing operation because it brings about undesirable changes in quality.

In, fluidized bed drying process, the drying completed mostly in falling rate period that can be subdivided into unsaturated surface drying region and internal movement of moisture-control region. The main purpose of this research was to find out the drying characteristics of beetroot at various combinations of air temperature and velocity using Fluidized Bed Dryer.

2. MATERIALS AND METHODS

A laboratory fluidized bed dryer was used for drying of the beetroot samples. All experiments were performed at the Department of Post Harvest Engineering and Technology, Aligarh Muslim University, Aligarh-202002, Uttar Pradesh, India. The setup was provisioned for air heating and air velocity control system. Figure 2 shows the process flow chart for dying beets in Fluidized bed dryer.

$$\text{Drying rate} = \frac{\text{Wt. of sample at time (t) - Wt. of sample at time (t+Dt)}}{\text{Time interval x Bone dry weight}} \times 100$$

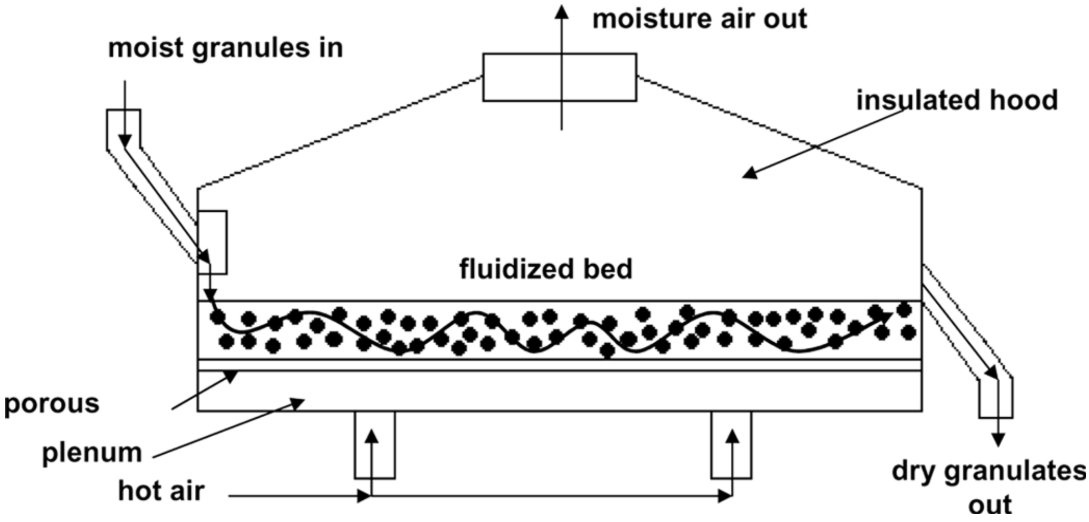

Fig. 1. *Concept of fluidized bed drying (Murthy and Joshi, 2007)*

$$\text{Moisture content (\%, db)} = \frac{\text{Loss in weight of samples}}{\text{Final (bone dry) weight of samples}} \times 100$$

Raw beetroots
↓
Washing (in water)
↓
Peeling (with the help of knife)
↓
Slicing (in slicer)
↓
Drying in Fluidized Bed Drying
↓
Packaging in bags (in LDPE with combination of aluminium coating)
↓
Storage (in clean & dry place)

Fig. 2. *Process flow chart for dying beets in Fluidized bed dryer (Kumar 2010)*

The drying chamber made by poly carbonates was used to accommodate the food material to be dried (Khan et al., 2015). The air velocity and the temperature distributions across the container were found to be uniform. Beetroots were dehydrated in the dryer at all combinations of air temperatures viz. 60°C, 67.50°C and 75°C and air velocities viz., 9 m/s, 10.50 m/s and 12 m/s to equilibrium moisture content (EMC). Response obtained by using response surface methodology. The observations made were: Initial moisture content of the sample (having 7mm x 7mm x 1mm size) and total drying time. Moisture content was determined by oven drying method (Ranganna, 1986). Drying rate was calculated using following equation as suggested by Jain and Singh (1997). Concept of fluidized bed drying is shown in figure 1.

3. RESULTS & DISCUSSION

The initial moisture content of beetroot for all samples was found to be 483.772-654.717 (%, db). The relationship between moisture content and drying times are calculated at different air temperatures viz. 60 °C, 67.50 °C & 75 °C. The moisture content decreased very rapidly during the initial stage of drying, while decrease in drying rate with respect to time. The trends of drying rates can be explained with respect to constant rate period and falling rate period. Thus, at 12 m/s air velocity the equilibrium moisture content (EMC) was the least as compared to those at other air velocities and at same temperature (Kumar *et al*., 2011). In fluidized bed dryer, in the initial stage of drying (up to 40-50 min) the moisture content of sample decreased rapidly with increase in drying time. Thereafter, the moisture content of samples decreased slowly with increase in drying time and attained final EMC. Figure 3 & 4 indicates the contour plot & 3D plot, showing dependence of desirability on inlet air temperature and inlet air velocity during fluidized bed dryer. It was also observed that the drying time of beetroot samples obtained from the fluidized bed dryer were ranges from 60 to 74 minutes; and final moisture content were ranges from 5.3 - 3.8 (%, dry basis), after complete drying upto EMC. While the optimum value of the response obtained by the response surface methodology were 75 ^{o}C temperature, average velocity 11.99 m/s, drying time 66.09 minutes for the final moisture content 3.45 % dry basis, of the beetroot dried in the fluidized bed drying (Kumar *et al*., 2014).

(A) Effect On Moisture Content During Fluidized Bed Drying:

The final moisture content of agricultural products plays an important role in maintaining the desirable quality of the product. The regression model for the moisture content (R^2=0.9848) was significant at $p \leq 0.05$. Only the linear and quadratic terms of inlet air velocity and inlet air temp significantly affected the moisture content. The coefficient of regression was good, but the 'lack of fit' significant and, therefore the model isn't acceptable. The regression model for the response (in terms of coded factors) is as follows:

Final moisture content (%, db) = $\mathbf{5.089161 - 0.26504 * A - 0.85798 * B - 0.09691 * A * B - 0.03986 * A^2 - 0.39879 * B^2}$

This regression equation shows the all factors in model, inlet air temp and inlet air velocity shows negative relation with model and the interaction between inlet air temp and inlet air velocity also shows a negative relation.

(B) Effect On Drying Time During Fluidized Bed Drying:

Drying time for dehydrated beetroots depends on factors like the, inlet air velocity, inlet air temperature, diffusivity of the free water out of the partially dried beetroot, resistance offered due to case hardening developed at the surface of the beetroot pieces, the partial pressure of the surrounding atmosphere, etc. The regression model for the drying time was significant at $p \leq 0.05$. The liner terms of inlet air velocity and inlet air temp significantly affected the drying time at $p \leq 0.05$. The regression model showed a coefficient of regression (R^2 = 0.6406) and a non-significant 'lack of fit' indicating that the model was adequately fitting to experimental data. The quadratic regression model in terms of coded factors is as given below:

Drying time (min) = 67.38095 - 5.83333 * A + 4.583333 * B

As can be seen from the regression model equation, inlet air velocity had positive correlation with the drying time whereas the inlet air temperature had negative correlation.

(C) Overall Optimization Of The Model:

The overall optimization was decided by setting the goals for each response. Here, goal means that what a given property (response) is desired to be, namely, should be the maximum; should be the minimum; should be within a range or should target to a specified value. For example final moisture content is desired to be the minimum, drying time is desired to be the minimum, inlet air velocity and inlet air temp within the range. Each response was given an importance value, ranging from plus three to plus five, depending upon their preference over the other responses. The importance values are subjective and therefore may be perceived differently. From all the available solutions, the one with high value for desirability was chosen.

Table 1. *Overall optimum constraints for fluidized bed drying of beetroot and values of weighted properties at optimum constraints*

Name	Goal/ desired	Importance	Optimum
Desirability	0.794	-	-
Inlet air temp (ºC)	is in range	3	75.00

Air velocity (m/s)	is in range	3	11.99
Drying time (min)	minimum	3	66.09
Final moisture content (%, db)	minimum	3	3.45

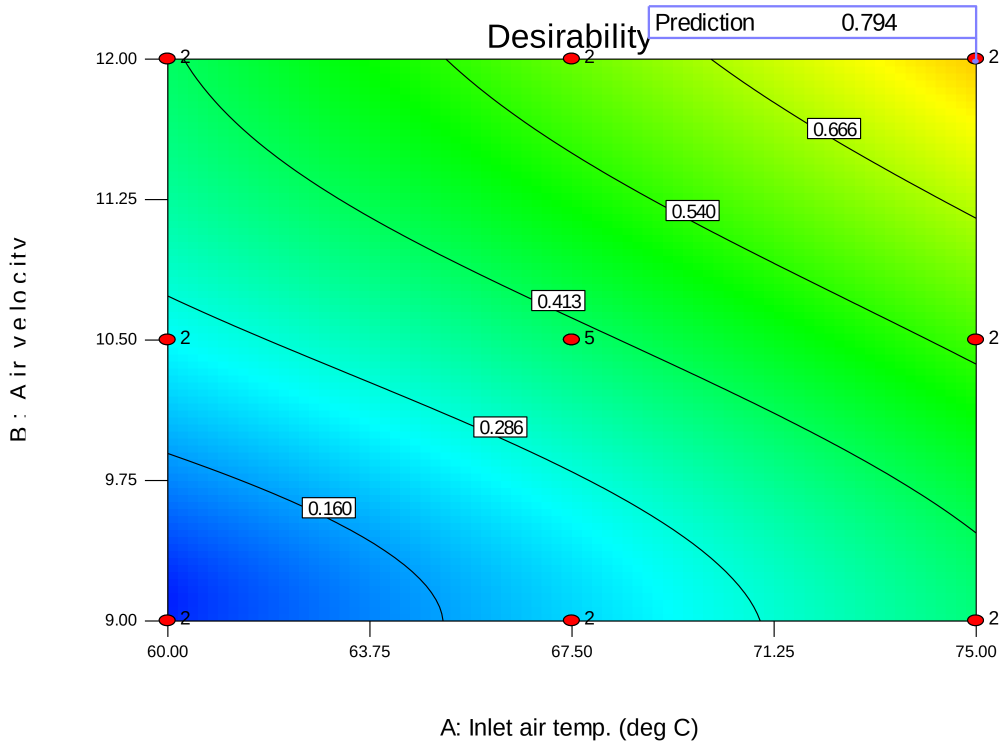

Fig. 3. *Contour plot showing dependence of desirability values on inlet air temperature and inlet air velocity during FBD (Kumar et al., 2012)*

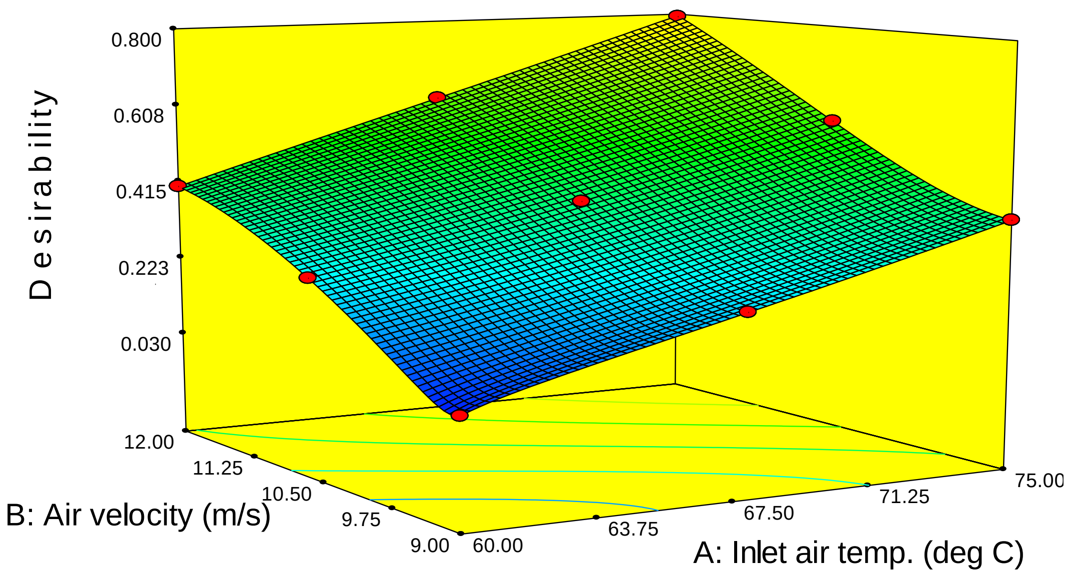

Fig. 4. *3D plot showing dependence of desirability values on inlet air temperature and inlet air velocity during FBD*

4. Conclusion

In the present preliminary study, beetroot has been dried by different methods; viz. sun drying, tray drying and fluidized bed dryer. The samples dried in fluidized bed drying is faster as compared to those dried in other method of drying. In fluidized bed dryer, moisture is lost in good extent as well as higher drying rate with lower final moisture content, as per the results obtained. Thus, it can be seen that fluidized bed dryer is a very prospective drying technique for increasing the shelf life of fruits and vegetables. The optimum operating condition obtained by the response surface methodology for the drying time was: inlet air temp 74.99999 ºC and inlet air velocity 11.98505 m/s which indicates drying time 66.085 min with desirability of 0.79403.

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