Microwave Assisted 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 microwave assisted fluidized bed drying (MAFBD) system. The results were compared with samples of beetroot dried in a fluidized bed dryer (FBD) at the same combination of temperatures and air velocities. 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. The MAFBD method offered two to three times reduction in drying time as compared to the FBD method. It was also observed that the beetroot samples obtained from the MAFBD system had lower final moisture content than those obtained from the FBD system.

Keywords: Microwave assisted fluidized bed drying; Fluidized bed drying; Beetroots; *Beta vulgaris L.*; Chukander.

INTRODUCTION

Drying is an excellent way to preserve foods that can add variety to meals and provide delicious and nutritious foods. One of the biggest advantages of dried foods is that they take much less storage space than canned or frozen foods. Drying is a difficult operation because it brings about undesirable changes in quality. The extent of changes in quality depends on the care taken in preparing the material before drying and on the drying process used [1]. Dried foods keep well because the moisture content is so low that spoilage organisms cannot grow. It also creates a hard outer-layer, helping to stop micro-organisms from entering the food. Drying is one of the oldest methods of preserving high moisture foods [2]. In Fluidized bed drying (FBD) process, the drying completed mostly in falling rate period. Further, the falling rate period can be subdivided into unsaturated surface drying region and internal movement of moisture-controlling region [3, 4]. In a study [5], it was reported the dehydration of aonla fruits in FBD time at 80°C with 115 m/min air velocity, 120 min. The results indicate the retention of ascorbic acid in the samples dried in fluidized bed drying is greater compared to those dried under sun and hot air tray. Using FBD, the drying time can be considerably reduced and the whole material can be uniformly dried [6,7,8]. In another study [9], it was reported the fluidized bed drying is a well-known process that has been widely used in the dairy and pharmaceutical industries for drying, granulating, and coating operations. Fluidized bed drying process has been successfully used to dry many agricultural products of different particle sizes (ranging from 10 mm to 20 mm) such as wheat and corn grains; and green peas [10].

Another method of drying is microwave drying. This drying facilitates heat transmission and mass transfer in the same direction, from the inside to outwards, because heat generation occurs not only at the surfaces but at inner sections of foods [11]. Microwave heating is rapid and more energy efficient compared to hot air drying. The amount of heat generated depends on the strength of the microwave field and the dielectric properties of the material being heated [12]. Microwave drying presents the following advantages over conventional thermal heating/drying methods: speed of heating (time saving), uniform volumetric heating, self regulating and automatic system, higher efficiency, lower cost of processing (low energy consumption) and compatibility with conventional heating [13].

In a study Goksu et al. [14] dried macaroni beads from about 20% to 12% moisture content using a fluidized bed of 7.6 cm dia, a domestic microwave oven with a power of 609 W and in the fluidized bed dryer placed in the microwave oven. At the first stage of the MAFBD, liquid water transports from the interior to the exterior of the particle by Darcy’s flow. As the temperature inside the material approaches to that of boiling of water, pressure development occurs pushing the moisture toward the surface. As the drying time proceeds, the liquid water supply cannot maintain the evaporation rate at the surface, and the moisture content near the surface decreases below critical moisture content. Darcy’s flow disappears so that liquid water has to be evaporated and then transported to the particle surface by vapor diffusion [15]. Combination of the two
methods can give rise to several desired results; the uniformity of the temperature among the particles can be provided by well mixing due to fluidization [16] and the drying times can be reduced by the utilization of microwave energy [17,18].

In the present study, focus is on the drying of beetroot using FBD and MAFBD. Beetroot (*Beta vulgaris* L.) commonly known as ‘chukander’, is mainly cultivated in India for its juice and vegetable value. It is a member of the flowering plant family Chenopodiaceae. The green leafy part of the beetroots is also of nutritional value, containing beta-carotene and other carotenoids. The nutritional benefits of beetroot are very well known. They are loaded with vitamins A, B, B2, B6 and C. The greens have a higher content of iron compared to spinach. They are also an excellent source of calcium, magnesium, copper, phosphorus, sodium and iron. Beetroot coupled with carrot juice, the excellent cleansing virtues are exceptional for curing ailments [19]. It contains high amounts of boron, which is directly related to the production of human sex hormones [20]. These findings suggest that beetroot ingestion can be a useful means to prevent development and progression of cancer. Extracts of beetroot also showed some antimicrobial activity on *Staphylococcus aureus* and on *Escherichia coli* and also antiviral effect was observed [21]. This nutrient is valuable for the health of the cardiovascular system [22]. The interest of the food industry in betalains has grown since they were identified as natural antioxidants [23] which may have positive health effects on humans [24]. Given the importance of beetroot its drying by the two methods was undertaken. The paper discusses the experiments conducted and compares the FBD results with those obtained by MAFBD.

Table 1: Nutritional value of beetroot per 100 g

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Amount</th>
<th>Constituents</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>9.96 g</td>
<td>Vitamin B6</td>
<td>0.067 mg</td>
</tr>
<tr>
<td>Sugars</td>
<td>7.96 g</td>
<td>Folate (Vit. B9)</td>
<td>80 µg</td>
</tr>
<tr>
<td>Dietary fiber</td>
<td>2.0 g</td>
<td>Vitamin C</td>
<td>3.6 mg</td>
</tr>
<tr>
<td>Fat</td>
<td>0.18 g</td>
<td>Calcium</td>
<td>16 mg</td>
</tr>
<tr>
<td>Protein</td>
<td>1.68 g</td>
<td>Iron</td>
<td>0.79 mg</td>
</tr>
<tr>
<td>Vitamin A equiv.</td>
<td>2 µg</td>
<td>Magnesium</td>
<td>23 mg</td>
</tr>
<tr>
<td>Thiamine (Vit. B1)</td>
<td>0.031 mg</td>
<td>Phosphorus</td>
<td>38 mg</td>
</tr>
<tr>
<td>Riboflavin (Vit. B2)</td>
<td>0.027 mg</td>
<td>Potassium</td>
<td>305 mg</td>
</tr>
<tr>
<td>Niacin (Vit. B3)</td>
<td>0.331 mg</td>
<td>Zinc</td>
<td>0.35 mg</td>
</tr>
<tr>
<td>Pantothemic acid</td>
<td>0.145 mg</td>
<td>Sodium</td>
<td>77 mg</td>
</tr>
</tbody>
</table>

**MATERIALS & METHODS**

A laboratory microwave assisted fluidized bed dryer and fluidized bed dryer was used for drying of the beetroot samples. All experiments were performed at the Department of Post Harvest Engineering and Technology (APFE), Aligarh Muslim University, Aligarh, Uttar Pradesh, India. The setup, Figure 1, was provisioned for air heating and air velocity control system. A drying chamber of circular cross section fabricated from Perspex pipe was prepared. A perforated Perspex plate, having an open area of about 50% of the base plate, was fitted in the bottom of drying chamber. This was used to accommodate the food material to be dried. The air velocity and the temperature distributions across the container were found to be uniform. Details of the experiments are given in Table 2. The drying was continued until the equilibrium moisture content was reached.

Table 2. Details of experiments

<table>
<thead>
<tr>
<th>Crop taken</th>
<th>Beetroot (Sanguina variety)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretreatment</td>
<td>Slicing to 7 mm x 7 mm x 1 mm size</td>
</tr>
<tr>
<td>Drying</td>
<td>Microwave assisted fluidized bed drying</td>
</tr>
<tr>
<td>Air velocity (A, V)</td>
<td>9 m/s, 10.50 m/s and 12 m/s</td>
</tr>
<tr>
<td>Air temperature</td>
<td>60°C, 67.50°C, and 75 °C</td>
</tr>
<tr>
<td>Control</td>
<td>Fluidized bed drying at same combination</td>
</tr>
<tr>
<td>Total number of experiments</td>
<td>21</td>
</tr>
<tr>
<td>Size of sample</td>
<td>200 g for microwave assisted fluidized bed drying and 500 g for fluidized bed drying.</td>
</tr>
</tbody>
</table>
The measurements were made of the following:
1. Initial moisture content of the sample.
2. Variation in moisture content of the product with drying time.
3. Total drying time for reducing moisture level up to equilibrium moisture content.

The drying calculations were done by this formula given below:

\[
\text{Moisture Ratio} = \frac{\text{Mt} - \text{Me}}{\text{Mo} - \text{Me}} \times 100 \quad \text{…….. (1)}
\]

Where
- \( \text{Mt} \) = Moisture content at any time \( t \)
- \( \text{Mo} \) = Initial moisture content
- \( \text{Me} \) = Equilibrium moisture content

\[
\text{Drying rate} = \frac{\text{Wt. of water removed}}{\text{Wt. of dry matter} \times \text{Time interval (min)}} \times 100 \quad \text{…….. (2)}
\]

\[
\text{Moisture content (%, db)} = \frac{\text{Wt. of moisture}}{\text{Wt. of dry matter}} \times 100 \quad \text{…….. (3)}
\]

\[
\text{Moisture content (%, Wb)} = \frac{\text{Wt. of moisture}}{\text{Wt. of sample (dry matter + water)}} \times 100 \quad \text{…….. (4)}
\]

The schematic of the experimental setup is depicted in Figure 1.

![Figure 1. Microwave assisted fluidized bed dryer](image)

**RESULTS & DISCUSSION**

The initial and final moisture contents of the sample were determined according to the standard oven drying method [25]. 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 is shown in Figures 2 to 4 at air temperatures 60°C, 67.50°C & 75°C. The moisture content decreased very rapidly during the initial stage of drying, as there was fast removal of moisture from the surface of the product in both the cases. Decrease in drying rate with respect to time suggests a decreased drying rate with the decrease in moisture content in both the cases. The trends of drying rates can be explained with respect to constant rate period and falling rate period [4]. Most food materials have short constant rate periods and they dry mostly in the falling rate period [7, 26, 27].
In case of FBD at 60°C air temperature and air velocity of 9 m/s, the moisture content of beetroot was reduced to 5.663 (% db) at the end of 75 min drying, but at the same temperature when air velocities were 10.50 m/s and 12 m/s, the moisture content values were 5.332 (% db) and 4.151 (% db) at the end of 80 min in both samples. At 67.50°C drying air temperature and air velocity of 9 m/s, the moisture content of beetroot was reduced to 5.485 (% db) at the end of 65 min drying but at the same temperature when air velocities were 10.50 m/s and 12 m/s, the moisture content values were 5.133 (% db) and 3.75 (% db) at the end of 60 min for both samples. At 75°C for air velocity 9 m/s, the moisture content of beetroot was reduced to 5.417 (% db) at the end of 75 min drying and at the same temperature when air velocities were 10.50 m/s and 12 m/s, the moisture content values were respectively 4.618 (% db) and 3.517 (% db) at the end of 75 min and 70 min drying respectively. In MAFBD at 60°C air temperature and air velocity of 9 m/s, the moisture content of beetroot was reduced to 5.244 (% db) at the end of 30 min drying, but at the same
temperature when air velocities were 10.50 m/s and 12 m/s, the moisture content values were 4.478 (%, db) and 3.618 (%, db) at the end of 30 min for both cases. At 67.50°C drying air temperature and air velocity of 9 m/s, the moisture content of beetroot was reduced to (%, db) at the end of 30 min drying but at the same temperature when air velocities were 10.50 m/s and 12 m/s, the moisture content values were 4.21 (%, db) and 3.425 (%, db) at the end of 25 min in both cases. At 75°C for air velocity 9 m/s, the moisture content of beetroots was reduced to 4.651 (%, db) at the end of 30 min drying but at the same temperature when air velocities were 10.50 m/s and 12 m/s, the moisture content values were respectively 3.933 (%, db) and 3.313 (%, db) at the end of 25 min in both cases. Thus at 12 m/s air velocity the equilibrium moisture content was the least as compared to those at other air velocities and at same temperature. In FBD, during the initial stage of drying (up to 40-50 min), the moisture content of sample decreased rapidly with increase in drying time. Similarly in MAFBD, during the initial stage of drying (up to 20-25 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 equilibrium moisture content. This may be due to the partial vapor- pressure of water present in sample; initially being more in comparison to that of the external environment (surroundings of the sample). At the initial stage of drying, moisture starts migrating rapidly from the sample to the external environment because of higher partial vapor pressure difference between sample and environment. As a result, the partial vapor pressure difference between the product and environment decreases rapidly, which leads to slower removal of moisture from the product and becomes constant at the end of drying. The equilibrium moisture content values were higher for sample dried at 60°C as compared to those dried at 67.50°C and 75°C.

CONCLUSION

Microwave assisted fluidized bed drying can greatly reduce the drying time of food materials with internal resistance to mass transfer. In the present preliminary study, beetroot (Beta vulgaris L.) has been dried by two different methods, viz., microwave assisted fluidized bed drying and fluidized bed drying. In both methods, moisture is lost in good extent. But the microwave assisted fluidized bed drying proved better than the FBD method in terms of reduced drying time and lower final moisture content, as per the results obtained. The future research on food drying will inevitably focus on lower energy costs, less reliance on fossil fuels, and reduced greenhouse gas emissions. In the attainment of these objectives MAFBD is expected to play a meaningful role as an attractive option for drying fruits and vegetables.

REFERENCES


