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Effect of Microwave on Fluidized Bed Drying of Beetroot *(Beta vulgaris L.)*

Yashwant Kumar[1], Mohammad Ali Khan[1] and Krishna Kumar Patel*[1]
[1]*Department of Post Harvest Engineering and Technology, Aligarh Muslim University, Aligarh-202002 (India)*

Abstract: - In the present work, an attempt has been made to study the effect of inlet air temperature and velocity on the drying characteristics of beetroot's (*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 selected inlet air temperatures and inlet air velocities were 60°C, 67.50°C and 75°C and 9 m/s, 10.50 m/s and 12 m/s, respectively. 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, etc.*

I INTRODUCTION

The excellent way to preserve foods is drying that is an oldest method of preserving high moisture foods [1]. 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. The extent of changes in quality depends on the care taken in preparing the material before drying and on the drying process used. Dried foods keep well because the moisture content is so low that spoilage organisms cannot grow. It also creates a hard outer-layer, help to stop micro-organisms from entering the food.

Moreover to above, the study by [3] on the dehydration of aonla fruits using FBD at 80°C with 115 m/min air velocity, 120 minutes (min) revealed that the retention of ascorbic acid is greater than sun and hot air tray dried samples. Thus, using FBD, the drying time can be considerably reduced and uniform drying of the whole material can be achieved [4, 5, 6]. With due to the several advantages, the fluidized bed drying process is now widely used for various applications in several agricultural sectors. For instance, in food processing, 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 [7]; in the dairy and pharmaceutical industries, for drying, granulation, and coating operations [8].

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 [9, 10]. On the other hand, in microwave drying, the 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 also presents several advantages such as speeded 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 over conventional thermal heating/drying methods [13].

Reference [14] dried macaroni beads from about 20% to 12% moisture content using microwave assisted fluidized bed (a fluidized bed of 7.6 cm dia and a domestic microwave oven with a power of 609 W) drier. To study MAFBD, they placed fluidized bed dryer in the household microwave oven and reported that at the first stage of the MAFBD, liquid water transports from the interior to the exterior of the particle by Darcy's flow and as the temperature inside the material approaches to the boiling point 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 these two methods can give rise to several desired results. Thus, 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_1, B_2, B_6 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 main purpose of this research was to fabricate a microwave assisted fluidized bed drier, to study the drying characteristics of beetroot at various combinations of air temperature and velocity using FBD and MAFBD.

II MATERIALS & METHODS

Material collection

Fresh and good quality beetroots of unknown variety were purchased from local market in Aligarh. By visual inspection damaged, immature and dried fruits were sorted out, manually. Beetroot of uniform size, free from pest and disease were selected for current research. After cleaning, washing, peeling and slicing, a laboratory fluidized bed dryer and self fabricated microwave assisted fluidized bed dryer (Fig. 1) were used for drying of the beetroot samples.

Microwave assisted fluidized bed drying

The fundamental fabrication criteria of microwave assisted fluidized bed drying is based on the study of [14]. The setup (Fig.1) was provisioned for air heating and air velocity control system. A domestic kitchen microwave oven (LG convection MWO type: Model: MC 9287 BQ, Korea) with a frequency of 2450 MHz was used. A drying chamber of circular cross section fabricated from perspex pipe fitted with a perforated perspex plate having an open area of about 50% of the base plate at the bottom was placed in a domestic kitchen microwave oven (LG convection MWO type: Model: MC 9287 BQ, Korea) with a frequency of 2450 MHz. 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. The schematic of the experimental setup is depicted in Figure 1. The measurements were made for (1) initial moisture content of the sample (2) variation in moisture content of the product with drying time and (3) total drying time for reducing moisture level up to equilibrium moisture content. The initial and final moisture contents of the sample were determined according to the standard oven drying method [25]. The drying calculations were done by the formula as given below:

$$\text{Moisture Ratio} = \frac{\text{Mt - Me}}{\text{Mo - Me}} \text{ x } 100 \qquad \text{........ (1)}$$

Where,

Mt	=	Moisture content at any time t
Mo	=	Initial moisture content
Me	=	Equilibrium moisture content

$$\text{Drying rate} = \frac{\text{Wt. of water removed}}{\text{Wt. of dry matter x Time interval (min)}} \text{ x } 100 \qquad \text{........ (2)}$$

$$\text{Moisture content (\%, db)} = \frac{\text{Wt. of moisture}}{\text{Wt. of dry matter}} \text{ x } 100 \qquad \text{........ (3)}$$

$$\text{Moisture content (\%, Wb)} = \frac{\text{Wt. of moisture}}{\text{Wt. of sample (dry matter + water)}} \text{ x } 100 \qquad \text{........(4)}$$

III RESULTS & DISCUSSION

Fig. 2 to 4 represent the effect of air velocities (9, 10.50 and 12 m/s) on relationship between moisture content and drying times at different air temperatures viz. 60°C, 67.50°C and 75°C for both FBD and MAFBD. 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 cases. Initial moisture content of beetroot for all samples was found between 483.772 and 654.717 (%, db). As drying progressed, the available moisture content on the surface of the beetroot decreases. Consequently, the drying rate of beetroot also decreases with respect to time in both drying methods. The trends of drying rates can be explained with respect to constant rate period and falling rate period [10]. Most food materials have short constant rate periods and they dry mostly in the falling rate period [5, 26, and 27].

Fluidized bed drying

At 60°C air temperature (Fig. 2) in FBD, the moisture content of beetroot decreases from 5.663 to 5.332 then 4.151 (%, db) while the drying time first increases then became constant from t_1 (75 min) to t_2 (80 min) and t_3 (80 min) as the air velocity increases from 9 to 10.50 then 12 m/s, respectively. However, when the temperature of air increase to 67.50°C (Fig. 3) both the moisture content and drying time decreases as per the air velocity increases. The moisture content of beetroot was recorded as 5.485, 5.133 and 3.75 (%, db) with respect to air velocity 9, 10.50 and 12 m/s at the end of 65 min, 60min and 60 min, respectively.

Similarly, at 75°C air temperature, the moisture content of beetroot was reduced to 5.417 (%, db), 4.618 (%, db) and 3.517 (%, db) as velocity increased from 9 to 10.50 then 12 m/s at the end of 75 min, 75 min and 70 min drying time, respectively.

Microwave assisted fluidized bed drying (MAFBD)

In MAFBD at 60°C air temperature and 9 m/s air velocity, the moisture content of beetroots was reduced to 5.244 (%, db) at the end of 30 min drying, but when air velocities increased to 10.50 m/s and 12 m/s, the values of moisture content were recorded as 4.478 (%, db) and 3.618 (%, db) at the end of 30 min for both cases. However, at 67.50°C drying air temperature and 9 m/s air velocity, the moisture content of beetroot was reduced to (4.851%, db) at the end of 30 min drying but at this temperature when air velocity increased to10.50 m/s and 12 m/s, the values of moisture content were 4.21 (%, db) and 3.425 (%, db) at the end of 25 min in both cases.

Furthermore, at 75°C for air velocity 9 m/s, the moisture content of beetroots was reduced 4.651 (%, db) at the end of 30 min drying while at same temperature when air velocity increased to 10.50 m/s then 12 m/s, the values of moisture content were noticed 3.933 (%, db) and 3.313 (%, db), respectively at the end of 25 min in both cases.

Thus, for all air temperatures, the minimum moisture content was recorded at 12 m/s air velocity as compared to the other air velocities.

Comparison between FBD and MAFBD

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.

IV 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.

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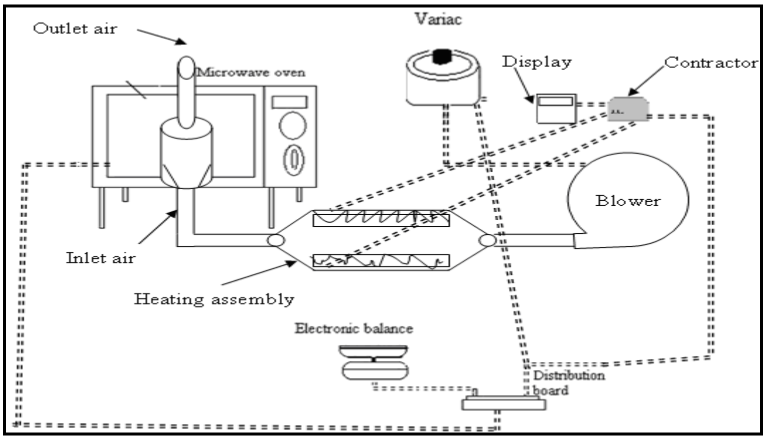

Fig. 1a Schematic diagram of microwave assisted fluidized bed drying system

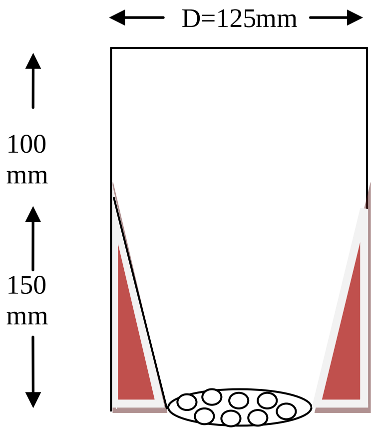

Fig. 2b Drying chamber in microwave assisted fluidized bed drying system

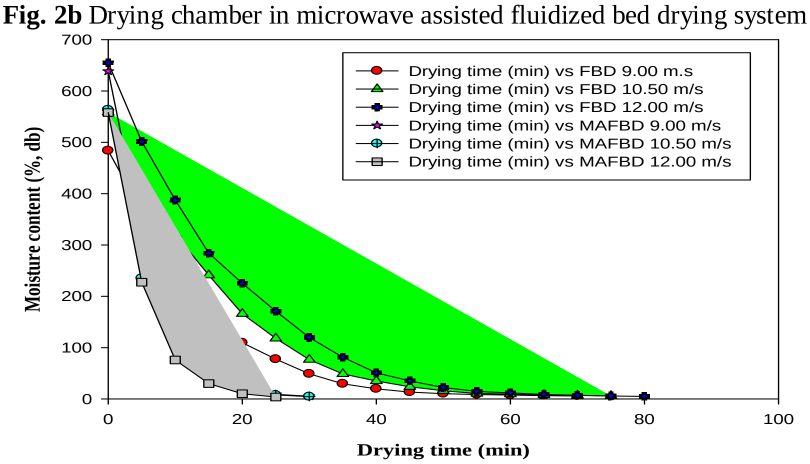

Fig. 2. Effect of velocity on moisture content during drying of beetroot in FBD and MAFBD at 60°C air temperature

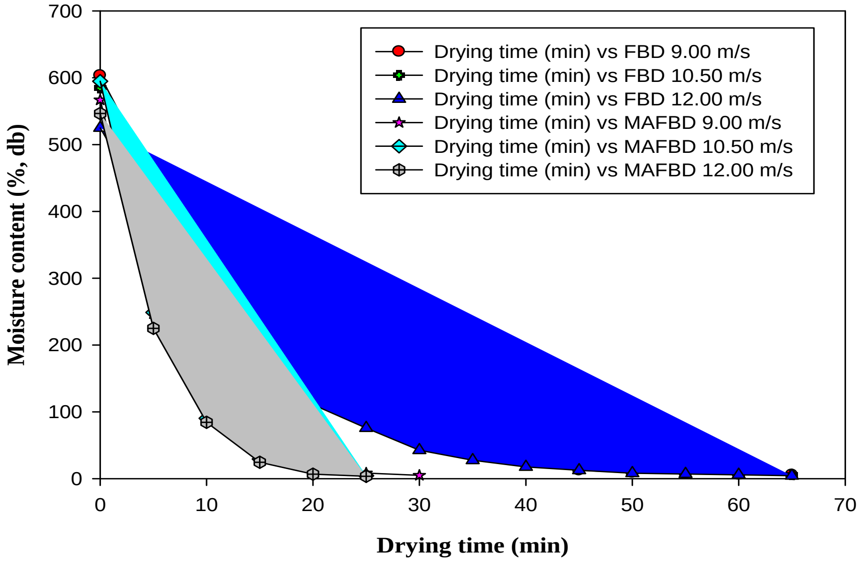

Fig. 3. Effect of velocity on moisture content during drying of beetroot in FBD and MAFBD at 67.50°C air temperature

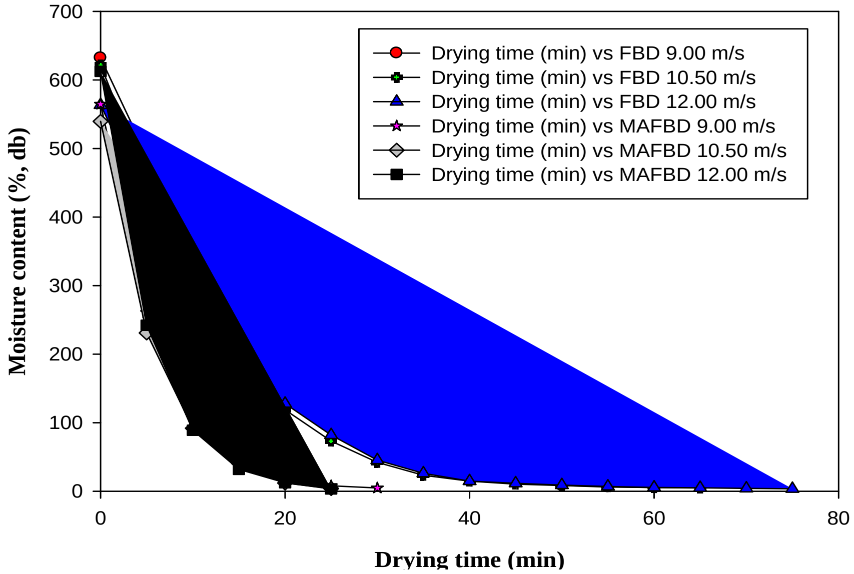

Fig. 4. Effect of velocity on moisture content during drying of beetroot in FBD and MAFBD at 75°C air temperature

Table 1. Nutritional value of beetroot per 100 g

Constituents	**Amount**	**Constituents**	**Amount**
Carbohydrates	9.96 g	Vitamin B_6	0.067 mg
Sugars	7.96 g	Folate (Vit. B_9)	80 µg
Dietry fiber	2.0 g	Vitamin C	3.6 mg
Fat	0.18 g	Calcium	16 mg
Protein	1.68 g	Iron	0.79 mg
Vitamin A equiv.	2 µg	Magnesium	23 mg
Thiamine (Vit. B_1)	0.031 mg	Phosphorus	38 mg
Riboflavin (Vit. B_2)	0.027 mg	Potassium	305 mg
Niacin (Vit. B_3)	0.331 mg	Zinc	0.35 mg
Pantothemic acid (B_5)	0.145 mg	Sodium	77 mg

Source: USDA national nutrient data base for standard reference, release 22 (2009)

Table 2. Technical details of microwave assisted fluidized bed drying equipment

Components and subcomponents of MAFBD		Technical details
1. Microwave (Model: MC 9287BQ, Made by Korea)		➢ Type: LG CONVECTION MWO (a domestic kitchen) ➢ Input and output power: 1950 and 900 watt ➢ Frequency: 2450 MHz ➢ Dimension: 574 mm x 376 mm x 505 mm.
2. Drying chamber	➢ Material used in construction	➢ Perspex and plaster of parish (POP)
	➢ Length of pipe,	➢ Total height 250 (100+150) mm (Fig.)
	➢ Top diameter,	➢ 125 mm
	➢ Distribution plate	➢ Made of perspex
	➢ Diameter of plate	➢ 60 mm
	➢ Diameter of hole	➢ 1 mm
	➢ Perforation	➢ 50%
	➢ Angle of taperness from the bottom	➢ 45^0 created by POP
2. Heating device/ assembly		Two electric heater
3. Motorized Blower (Made by Lama Electricals Azad factory and Model: 75 impellers)		➢ Used for fluidization of beetroots using air ➢ Horse power: 1,Voltage: 180-230 and Frequency: 50 cycle
4. Variac (Made by B. R. Trading Company, India)		➢ Used to adjust AC voltage ➢ Maximum load: 10 Amps (for input 240 V, 50/60 Hz) ➢ Output varied between 0 to 270 volt
5. Data logger		➢ Used to measure the outlet temperature and humidity ➢ Input: .230-240 V AC, Fuse: 200ml, Frequency: 50 Hz
6. Voltage Stabilizer (Made by CYBEX)		➢ to maintain the constant voltage supply to experimental setup ➢ Capacity: 3 kVA, servo type
7. Electronic balance (Made by Atcom Technologies Ltd.		➢ Capacity: 0.1 g to 5000g ➢ Voltage supply: 9V

Table 3. Details of experiments

Particulars	Details
Crop taken	Beetroot (Sanguina variety)
Pretreatment	Slicing to 7 mm x 7 mm x 1 mm size
Drying	Microwave assisted fluidized bed drying
Air velocity (A.V)	9 m/s, 10.50 m/s and 12 m/s
Air temperature	60°C, 67.50°C, and 75 °C
Control	Fluidized bed drying at same combination
Total number of experiments	21
Size of sample	200 g for microwave assisted fluidized bed drying and 500 g for fluidized bed drying.