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Studies on economic feasibility and effect of drying time on outlet air humidity during fluidized bed drying of beetroot (*Beta vulgaris* L.)

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Abstract
Drying is an oldest, efficient and inevitable technology among the food preservation techniques. This technique is significant in reducing of the post harvest loss of the fruits and vegetables. Although, there is strong need for an efficient and cost effective drying technology that reduced the drying time, improve the product quality and enhanced the flexibility in various types of drying products. Beetroot is a second largest sugar crop and has utmost important at commercial level due to presence of several medicinal values. For instance, presence of antioxidant in beetroot helps us in protecting heart and also in preventing cancer. But due to loss of water, sprouting and diseases (bacterial rot, black rot, Rhiizoctonia violacea and Scierotinia scierotiorum) causes of post harvest loss of beetroot in terms of nutritional and market values. the drying of beetroot is, thus, very important to avoid postharvest loss and to preserve the quality and consequently the medicinal values. Fluidized bed drying is very efficient drying method has been used in this study and checked the effect of drying time on outlet air humidity. The feasibility economic of product development was also analyzed in this study. At initial stage of drying outlet air humidity is increasing with respect to drying time, while after some time it deceases by further increase in drying time. The FB dried products had good quality pursuantly texture, flavor and taste.

Keywords: Drying time, outlet air humidity, fluidized bed drying (FBD), beetroot and drying

Introduction
Drying is the most common, popular and an ancient method or unit operation of preservation of food and agricultural produce (Khan *et al.*, 2015; Patel *et al.*, 2012) [9, 15]. Compared with other methods, it is quite simple and easy to handle to everyone. Dried foods keep well because the moisture content is so low that spoilage organisms cannot grow. Drying will never replace canning and freezing because these methods do a better job of retaining the taste, appearance, and nutritive value of fresh food. But drying is an excellent way to preserve foods that can add variety to meals and provide delicious and nutritious food. One of the biggest advantages of dried foods is that they take much less storage space than canned or frozen foods. Although, solar drying is a popular but it is very inexpensive method. Dependable solar dehydration of foods requires 3 to 5 consecutive days when the temperature is 95 ºF (35 ºC) and the humidity is very low hence solar drying is thus not feasible. In contrast tray, rotary, flash, spray, fluidized bed, vacuum, freeze and batch dryers are classified as conventional and there is great number of areas suitable for further improvement (Patel *et al.*, 2012) [15].

Water is usually removed by evaporation (air drying, sun drying, smoking or wind drying). Bacteria and micro-organisms within the food and from the air need the water in the food to grow. Drying effectively prevents them from surviving in the food. It also creates a hard outer-layer, helping to stop micro-organisms from entering the food (Patel *et al.*, 2014) [14]. In addition to preservation, drying reduces mass and volume of product by a significant amount and improves the efficiency of their transportation and storage. Often, the drying of food results in a product that is more convenient in use. Besides providing fiber, fruits and vegetables are also important sources of essential dietary nutrients, vitamins and minerals. Since fresh fruits and vegetables have moisture content higher than 80% (wb) and short shelf lives, they are classified as perishable commodities. Keeping the produce fresh is the best way to maintain its values, but most storage techniques require a low temperature which requires high cost. Therefore, drying is more suitable for post-harvest management (Chauhan and Srivastava, 2009) [3].

Drying refers commonly to the removal of water from substances by applying heat. However, the removal of other liquids such as organic solvents is also referred to as drying. In addition, there are various methods other than thermal drying such as mechanical means of removing of liquids. Therefore, general definition may be the removal of volatile substances from a mixture that yields a solid product. Commonly, the principal volatile substance is water (Geankoplis, 1993; Treybal, 1981) [4, 19]. The fluidized bed drying technique holds an important position among modern drying methods. It is widely used mainly for granular materials and also applicable in the drying of solution, pastes and liquids sprayed on the fluidized inert bed the principle of operation of the fluidized bed dryer is to provide sufficient air pressure to fluidize a thin bed of grain/product, giving excellent air/grain contact. Above a certain pressure, related to the weight per unit area of the grain bed, the pressure drop across the bed becomes constant, with volume flow rate, so that the fast drying can occur.

Fluidized bed drying has been recognized as a smooth, uniform drying method, capable of drying down to very low residual moisture content with a high degree of efficiency (Borgolte and Simon, 1981) [2]. This process is characterized by high moisture and heat transfer rates and excellent thermal control capacity compared with conventional drying processes (Hovmand, 1987) [6]. It is also a very convenient method for drying heat sensitive food materials as it prevents them from overheating due to mixing (Gibert *et al*., 1980) [5]. The use of fluidization is one of the technologies commonly used in drying agro-food materials. Fluidized bed technology has been widely used in the food industry for drying and the product quality is controlled (Khan *et al*. 2015) [9]. The continuous fluidized bed dryer significantly reduces drying time compared with tray dryer or vacuum dryer. A diffused plate forms porous base of fluidized bed. Drying process allowed proper fluidization of granules and provided enough time to allow diffusion of the moisture from the granulation core to the surface (Naveen *et al*., 2009) [13]. Fluidized bed drying can be carried out as a batch or continuous process (Shilton and Niranjan, 1993) [18]. The microwave assisted fluidized bed drying provides unique opportunities in the development of advanced food drying technologies.

Beetroots (*Beta vulgaris L.*) commonly known as chukander in Hindi is mainly cultivated in India for its juice and vegetable value. It is a member of the flowering plant family Amaranthaceae or Chenopodiaceae. The green leafy part of the beetroots is also of nutritional value containing beta-carotene and other carotenoids. Carotenoids function as antioxidants. The yellow, orange, and many of the red pigments in fruits, vegetables, and plant materials are usually carotenoids) (Kumar 2010) [10].

The nutritional benefits of beet root is very famous, beets 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 (Mathangi 2019) [12]. While the sweet beetroot has some of the minerals in its greens to a lesser degree, it is also a remarkable source of chlorine, folic acid, iodine, manganese, organic sodium, potassium, fiber and carbohydrates in the form of natural digestible sugars. Its iron content, though not high, is of the highest and finest quality that makes excellent food that is blood building. This renders it highly effective in treating many ailments caused by our toxic environment and surrounding. Beetroots have higher sugar content than most vegetables. Beetroots come in all shapes and sizes but the most common is round and deep red in color. The roots and greens therefore are great for women in general and for those planning pregnancy. Beetroot has anti-carcinogenic substances and it is a great source of fibre. In addition, betalains pigments are the collective form of betacynin (Patkai *et al*., 1997) [16] and betaxanthin are also presents in beetroot have antioxidant properties reduce the risk of cancer in human beings (Kavalcova *et al*., 2015) [8]. Beetroot purifies the blood and improves the circulation. It is a silicon rich vegetable which helps the absorption of calcium. Beetroot, thus, also known as the table beet, garden beet, red beet or informally simply as beet.

Beetroot is cultivated as sugar beet and closely related to mangel-wurzels (*Beta vulgaris*) has a sucrose content. In Britain and European countries, production of sugar from beetroot has now become very large industry due to high its demand since over the centuries. Although Mangel-wurzels were primarily grown for cattle feed, Mangel-wurzels were eaten in the times of famine in many parts of England and Europe. Initially, the large roots (5 to 10 cm) of beetroot were consumed as salad in the form of slice and small whole roots (2 to 5 cm) of beetroot were canned before consumption. Beetroot, however, has probably been eaten since Roman times. But beetroot plant was native to Eurasia and later expanded from India to across the continental Europe by the mid-nineteenth century. However, since beginning sometime in the middle of the second millennium only, the leaves of the plant were consumed. Later beetroot was used in the production of sugar in 18th century. Now people are more aware about the beetroot as an edible vegetable (Anon 2001) [1].

The present study was carried out with the following objectives- Drying of beetroot using fluidized bed dryer at different temperature and air velocity; and comparison of drying characteristics of beetroot dried in fluidized bed dryer.

Materials and Methods

Experiments were carried out to study the effect of inlet air velocity on drying time of beetroot (*Beta vulgaris L.*) pieces in an experimental fluidized bed drying method. A batch type fluidized bed dryer was used for this purpose. The entire experimental studies were conducted in the Department of Post-Harvest Engineering and Technology, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh, India; where well-established facilities are available. Details of experimental design, experimental setup and procedure are reported in following sections.

Experimental Designs

Raw materials

Good quality of fresh beetroot was procured from the local market of Aligarh. The damaged, immature and dried fruits were removed manually by visual inspection while beetroot of uniform size free from pest and disease was taken for experiment.

Experimental plan

Based on the previous report of literatures, the experimental plan was devised. Beetroot are cleaned, washed, peeled and sliced. Then FBD system was used for drying of beetroot. The equipment’s and instruments available in the department - Fluidized bed dryer, electronic weighing balance, data logger, digital temperature meter, hot air oven, anemometer, knife, desiccator, heat sealer, beetroot slicer and beetroot dresser were used. Experimental variables/ parameters and their levels and description are given in following –

Table 1: Details of variables / parameters and their levels and description

S. No.	Variables/parameters	Level	Description
1	*Independent dryer parameters*		
	• Inlet air temperature.	3	60, 67.50 and 75 °C
	• Inlet air velocity.	3	9, 10.5 and 12 m/s
2	*Measuring parameters*		
	Humidity	3	Humidity of outlet air from FB dryer.
	Sample weight	3	At every 5 minute interval.

Experimental Set Up

Fluidized bed dryer

This is a dryer in which moisture removal takes place by fluidization of solids with hot air. This setup fitted with specially designed vertical Polycarbonate glass column (Plate 3). The lower conical portion of the column is fitted with fluidizing material. The materials are supported on the screen mesh held between two flanges. Air from a compressor is heated in the heater box and passed through the column. Flow control and by pass valve are fitted to regulate the airflow. Electricity (220 volt AC, 3 kW with one phase) supply and free flow solids (beetroot particles) are the main utilities required in this research. The column was made of polycarbonate glass (dia. 80 mm, total length 500 mm with one end conical shape), air was supplied using compatible system (9 m/s, 10.50 m/s & 12 m/s), and a compatible capacity fitted with nichrome wire heater was used as heating chamber. The range of temperature controller was 0-300 °C and the range of temperature of inlet and out was 40-120 °C and 40-120 °C, respectively. The range of timer was 0 to 60 min and capacity of chamber was 350-1500g. Similarly, the specification of drying chamber specified was; top diameter: 20 cm, total height: 34 (14+20.5 from the top) cm and the angle of taperness from bottom: 45^0.

The air velocity inside drying chamber was measured with help of a vane type digital readout anemometer (Make: Lutro; Model: AM-4201), which was kept in such a way that its vane remaining vertical and faced the direction of air flow. The range anemometer was 4-30m/s, 1.4-108 km/hr, 8-58.3knots. The reading of the anemometer was recorded for one-minute duration.

Hot air oven (Make: Yarco, Model: YSI-431), electronic balance, heat sealing machine, motorized blower (Make by: Lama Electricals under license from Azad factory, Model: 75 impellers), dessicator, data logger, variac, voltage stabilizer, etc. were also used in this research. In addition, the variac used in the experimental setup (Make by: B. R. Trading Company) was able to bear a maximum load of 10 Amps for input supply of 240 V, 50/60 Hz. The output given by variac can be varied from 0 to 240 V at point A & C, and from 0 to 270 V at point B & C. Data logger (input: 230-240V AC, 50 Hz frequency) was used for the measuring the outlet temperature and outlet humidity. A 3 kVA servo type voltage stabilizer (Make: CYBEX) was used to maintain the constant voltage supply to the experimental setup.

Method for drying sample preparation and drying of beetroot

Several steps washing, peeling, slicing, drying, etc. are used in preparation of dried beet root. Beetroots were washed to remove adhering dust, dirt and soil to reduce the number of contaminating microorganism on the raw material. The beetroot were dipped in the water for 15 min to swell the adhering soil and washed with hand in the running tap water. The surface moisture was absorbed using blotting paper and peeled the washed beetroots with the help of knife. All the traces of skins and other infected portion were removed by peeling very carefully.

The surface of beetroots was made smooth, round or oval so that circular chips were obtained. Peel was collected and weighed for circulation of peeled loss.

Such peeled beetroots were sliced into chips of 1 mm thickness with the help of slicer (Made by Sirman S.P.A.V. Venezia, 235010, Marsango, Padova, Italy; Model: Topaz 220), which is available in laboratory.

Drying of beetroot chips

Fluidized bed dryer was used for the drying of beetroot. Using samples (size 500 g), three inlet hot air temperatures 60 ºC, 67.50 ºC and 75 ºC and three air inlet velocities (9, 10.50 and 12 m/s) for each temperatures, this research was carried out. The drying was carried out until the constant weight was achieved. Sample was weighed at 5 min interval for determining the moisture content. Drying time was kept between 80 min and 105 min depending upon the inlet air temperature and air velocity.

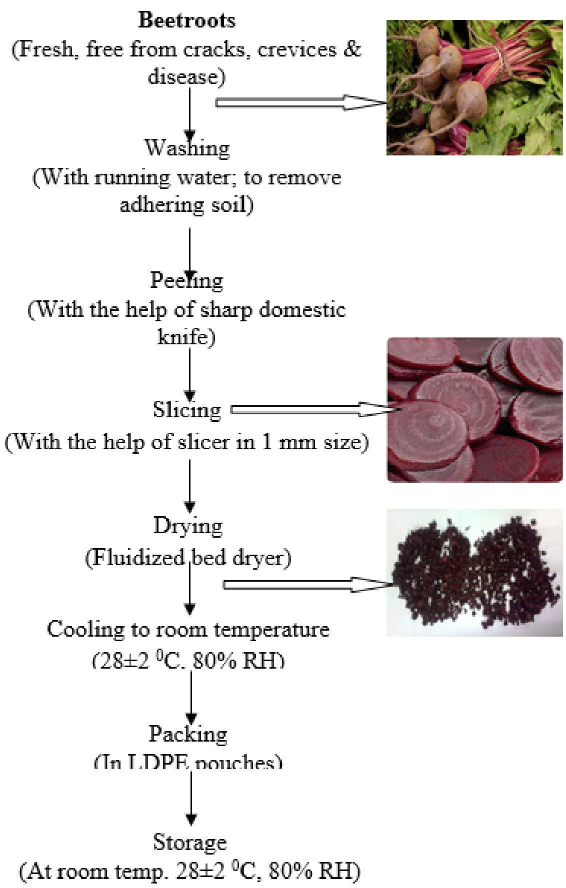

Fig 1: Process flow chart for dying beets in FBD bed drying (Kumar 2010)

Flow diagram of drying of beetroot chips is given in Figure 1. The dried beetroot were packed in aluminum coated LDPE (low density poly ethylene) bags and stored at dry and clean place at room temperature.

Determination of Experimental Parameters

Initial moisture content

Initial moisture content of beetroot was determined by hot air oven method as recommended by Ranganna (1986) [17]. The 5 g of samples (each) were weighed in petridishes with flat-bottom of lower in shape. These petridishes containing the samples were placed into hot air oven and maintained the temperature of oven at 60-80 ºC. The cover was removed before placing into hot air oven. After 16-18 hr of drying, petridishes were taken out from the oven, covered with its lid and put into desiccator. The Petridishes were cooled and weighed. Moisture content of samples was determined using following formula:

$$Moisture\ Content\ (\%, db) = \frac{Loss\ in\ weight\ of\ samples}{Final\ (bone\ dry)\ weight\ of\ sample} \times 100 \quad (1)$$

Analysis of drying rate and moisture content during drying

Moisture content of samples during drying was computed through the mass balance. For this purpose, weight of sample during drying was recorded at predetermined time interval (5 min). Using formulae (2 & 3) moisture contents were calculated while drying rate was calculated using equation (4), suggested by Jain and Singh (1997) [7].

$$Weight\ of\ bone\ dry\ material\ (W_d) = \frac{Initial\ weight\ of\ samples-(100-Initial\ moitutre\ content)}{100} \quad (2)$$

$$Moisture\ Content\ (\%, W_b) = \frac{(Weight\ of\ sample\ at\ any\ time-W_d)\times 100}{W_d} \quad (3)$$

$$Drying\ Rate = \frac{W_t - W_{t+D_t}}{D_t \times W_d} \quad (4)$$

Where, W_d is weight of bone dry material of substance (g); drying rate, g of average water removed/min/g of dry matter; W_t is weight of sample at time ‘t’ in gram; W_{t+Dt} is weight of sample at any time,‘t+D_t’, in gram; ‘D_t’ is the time interval (min) and W_d is weight of bone dry material in gram.

Economic analysis for fluidized bed dried beetroots

Economics feasibility analysis was carried out for the drying and of beetroots and for this purpose several assumptions were taken into the consideration. Some are given below in the Table 2.

Table 2: Assumption considered for economic analysis of beetroots drying.

S. No.	Items/Facts	Value/life assumed
1.	Life of fluidized bed dryer	20 Year
2.	Life of slicer	10 years
3.	Life of packaging machine	20 years
4.	Life of electric weighing machine	10 years
5.	Salvage value of fluidized bed dryer, slicer & packaging machine and weighing machine	10% of initial cost
6.	Interest rate / year	10% of initial cost
7.	Operation / day	8 hr
8.	Wages / day / labour	Rs 150/-
9.	Annual maintenance and repair	2% of initial cost
10	Labour required	1
11.	Capacity of fluidized bed dryer	0.5 kg/hr
12.	**Fixed cost**	
	Cost of fluidized bed dryer	Rs 78000.00
	Cost of slicer	Rs 2000.00

For the analysis of economics of drying some economic indicators such as payback periods, return on investment, benefit cost ratio, and break-even point were worked out for this study. Break Even Point for no. of days (D) to be breakeven point in days, payback periods, and return on investment and benefit cost ratio can be calculated using the equation (5), (6) (7) and (8), respectively as given below.

$$\text{Fixed cost} + \text{Variable cost} \times \text{Days (D)} = \text{Revenue per day} \times \text{Days} \quad (5)$$

$$Payback\ Period = \frac{\text{Total capital investment+Working capital}}{\text{Net annual profit+Depreciation}} \quad (6)$$

$$Return\ on\ Investment = \frac{\text{Net annual profit}}{\text{Total capital investment+Working capital}} \times 100 \quad (7)$$

$$Benefit\ cost\ ratio = \frac{\text{Annual benefit}}{\text{Total annual cost}} \quad (8)$$

Results and Discussion

Effect of drying time on outlet air humidity

The humidity of air exist from the outlet of fluidized bed (FB) dryer for different combination of drying temperature and air velocity was estimated at every 5 minutes of interval during drying of beetroots. The data logger recorded the outlet air humidity at a given time and found that the humidity of outlet air from FB dryer was decreased as the air velocity increased. Means humidity was recorded lower for the high velocity drying air. Although, the humidity of outlet air from FB dryer was observed higher for higher drying temperature for a given time and a particular air velocity. This was found might be due to the high temperature of beetroots and less time of contact for a particular air with samples. During this period or time of contact, the sample releases higher moisture due to high temperature and the vapour density in outlet air, thus, was higher (Figure 2).

At a fixed drying temperature for higher air velocity the contact time of a particular air to the beetroots sample was lower leads to the lower outlet air humidity. But at a fixed air velocity for higher drying temperature, the temperature of beetroots sample was lower compared to the inlet air temperature leads to the higher outlet air humidity.

The effect on outlet air humidity of samples under fluidized bed drying with drying time is shown in Fig 2. From the Figure 2, it can be observe that humidity of outlet air from the fluidized bed dryer first increased slightly with increase in drying times and then decreased very sharply and subsequently after 50 to 70 min of drying attained nearly constant value.

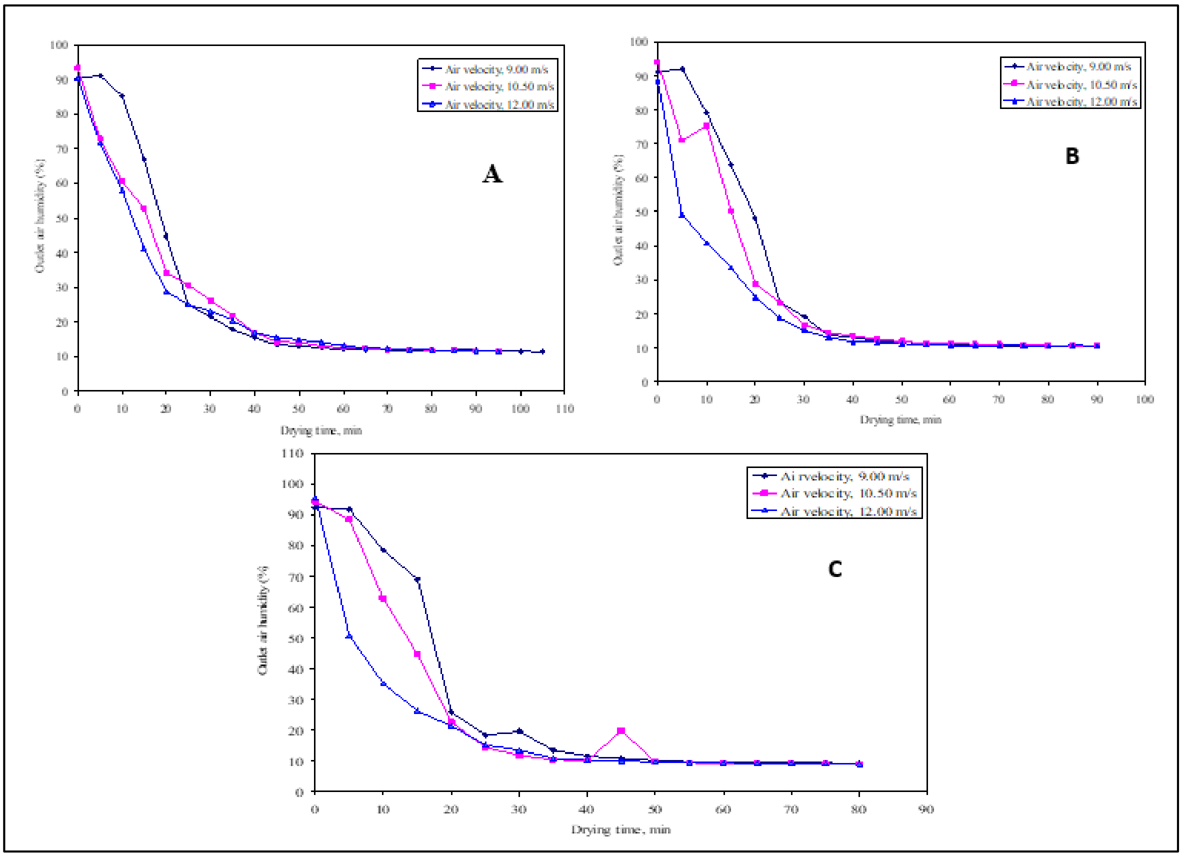

Fig 2: Effect of air velocity on outlet air humidity of beetroots during drying at different inlet air temperatures (a) 60 ºC, (b) 67.50 ºC and (c) 75 ºC during FB drying.

From Figure 2, it is also clear that as the temperature of drying air increased, the time of beginning constant drying decreased. For inlet air temperature 60 ^{0}C, 67.5 ^{0}C and 70 ^{0}C, the time for attainment of constant rate drying were about 70 min, 60 min and 50 min, respectively. This was might be due to fast surface drying and results of formation of hard surface layer due to high air inlet temperature and presence of sugar in beetroot sample. The movement of inner moisture further reduced due to hindrance of hard layer on the surface of the sample. In contrast to this, in the case of drying at lower inlet air temperature the movement of moisture was not hinder by the hard surface layer.

However, it noticed that at the initial stage of drying, the temperature of the beetroots sample was lower in comparison to the inlet air temperature the moisture started migrating rapidly from the sample to the surrounding and the outlet air humidity increased with time but after some period drying, the slow removal of moisture led to decrease the humidity of outlet air and subsequently at a nearly constant value. Similar results have also been reported by Kumar *et al.* (2014) [11] during the fluidized bed effect of microwave on fluidized bed drying of beetroot. They have reported that the moisture content of beetroot decreases while the drying time first increases then became constant as the air velocity increases when air temperature was kept constant at 60 ^{0}C. But when air temperature kept constant at 67.50°C, the moisture content and drying time decreases both were found to be decreased with the increment in the air velocity. Similar pattern was also noticed when air temperature was further increased to 75 ^{0}C. In addition, Khan *et al*. (2015) [9] have also reported that the product dried using MW assisted fluidized bed dryer had good quality in terms of colour values.

Economic Feasibility Analysis

Cost of packaging machine	Rs 7000.00
Cost of electric weighing machine	Rs 10000.00
Total initial cost	Rs 97000.00

(1). Annual depreciation

(a). Depreciation on fluidized bed dryer

= (Cost of machine – salvage value of machine) / useful life

= (78000 - 7800) / 20 Rs 3510.00

(b). Depreciation on slicer
= (2000 - 200) / 10 Rs 180.00
(c). Depreciation on packaging machine
= (7000 - 700) / 20 Rs 315.00
(d). Depreciation on electric weighing machine
= (10000 - 1000) / 10 Rs 900.00
Total depreciation Rs 4905.00
(2). Annual interest on investment @ 10% of initial cost
Rs 9700.00
(3). Annual maintenance cost @ 2% of initial cost
Rs 1940.00
(4). Housing rent cost @ Rs 1000 / month (1000 * 12)
Rs 12000.00
Annual fixed cost Rs 28545.00
Fixed cost / day (28545 / {12 * 30}) Rs 79.29
(B). Variable cost / day
(1). Labour cost @ Rs 150 / day / labour Rs 150.00
(2). Raw material cost @ Rs 10 / kg (4 * 10) Rs 40.00
(3). Electric cost @ Rs 4 / unit
Units consumed = (slicing + drying) * 8 = (0.0125 + 1.0) * 8
8.1 units
Electric cost = 8.1 * 4 Rs 32.4
(4). Packaging material cost @ Rs 60 / 80 packet
= (8 * {60 / 80}) Rs 6
Total variable cost / day Rs 228.4
Total cost / day = Total fixed cost + Total variable cost
= 79.29 + 228.4 Rs 307.69
Cost of production
Total production / day = (8 * {77.42 / 500}) Rs 1.24
Cost of production / kg = (307.69 / 1.24) Rs 248.137

The 500 g / batch capacity of the lab model based fluidized bed dryer produces 1.24 kg dried beetroot per day. The cost of production of dried beetroots was higher because of the lower capacity of the lab model fluidized bed dryer. If the study is carried out on prototype of a fluidized bed dryer then it may become economical.

Conclusion
Beetroot is a significant vegetable in terms of its medicinal and commercial values. Betalain, a very active water soluble nitrogen containing pigment and plays an important role to maintain our health, is abundant in beetroot. But due to due to seasonal availability and high post harvest loss its availability to the consumer is limited and consequently its consumption popularity is not up to the mark as per its medicinal contents. As, the present study has also been provided basic information of economic feasibility of drying of beetroot, this research could help not only the researchers but also to the drying industries during mechanical fluidized bed drying of beetroot for the production of commercial level dried beetroot's chips and powders. After drying, importance of dried product will also increases due to application varieties.

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