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Research Article

EFFECT OF DRYING TEMPERATURE AND SLICE THICKNESS ON CHARACTERISTICS OF BEETROOT (*Beta vulgaris* L.)

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Abstract: Beetroot is a biennial root vegetable grown all over the world and also known as *Beta vulgaris* L. Beetroot is a rich source of vitamin C (12.33 mg/100g) to human beings. Dried beetroot can be consumed in the form of chips, as a replacement for potato or corn flakes and also as an ingredient of instant food. Beetroot powder has a natural red colour and can be used as food colouring agent in salads, jams, jellies, deserts, ice creams, beverages and many nutraceutical products and substitute for artificial red colour. The beetroot slice was dried in tray dryer with five levels of drying temperature (55, 60, 65, 70 and 75 °C) and five levels of thickness (2, 3, 4, 5 and 6 mm). The observations on reduction in weight were taken regularly after interval of 30 minutes till the constant weight is achieved. Proximate analysis was carried out before and after drying of beetroot. The maximum ascorbic acid (14.10 mg/100g) and betaine (88.52 mg/100g) content was found during 60 °C drying temperature with 5 mm slice thickness of dried beetroot. The protein content, fat content and crude fiber content was decreasing with increase in drying temperature and slice thickness of dried beetroot.

Keywords: *Beetroot, Drying, Slice thickness, Drying temperature and proximate characteristics*

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Introduction

Vegetables are highly perishable, seasonal and available in plenty at a particular area bringing complexity in its post-harvest processing. In peak season, prices fall steeply and producers have to sell at throw away prices. *Beta vulgaris* L. commonly known as the red beet or beetroot is a biennial root vegetable grown all over the world and cultivated in loam, sandy loam, and clay loam soils. The yield of beetroots varies from 25 to 30 t/ha [1] and especially rich in fiber as well as in sugars, but has moderate caloric value. Beet roots deep red-colored are the most popular for human consumption and is consumed as soups or on salad as well as cooked with other vegetables and also can be eaten raw or roasted.

Recent studies have shown that consumption of beet juice may improve performance in endurance sports [2]. Beetroots are a rich source of vitamin C, potent antioxidants and nutrients, including magnesium, sodium, potassium, and betaine, which is important for extended the self-life, cardiovascular health, medicinal properties improving the digestion and blood quality and better handling beetroot juice can be converted into beetroot powder [3]. Drying is a major heat energy consuming operation in agro processing industries. The potential problems associated with solar drying such as the inability of commercial and community producers to process agricultural and fishery products during inclement weather conditions and night time. An alternative energy source provides the ability for the producers to continuously process food products with reliability. Biomass resources particularly agricultural residues appear to be the most common source of energy in rural and marginalized communities of many developing countries. A biomass fuelled energy source integrated to the dryer as a separate component will solve the weather dependent conditions. In many countries, large amount of food products are dried to improve shelf life, maintain nutritional value, reduce packaging costs, enhance appearance, retain original flavour and lower weights [4]. The post-harvest losses of fruits and vegetables are estimated to be 30-40% of the production [5]. Drying process plays an essential role in the preservation of agricultural produces [6]. It enhances the shelf life and reduces water activity [7]. Beets are composed of 87.57% water, 9.56% carbohydrates (29.3% fiber and 70.7% sugar), 1.61% protein, and 0.17% lipids in addition to being a source of potassium, choline, vitamin C and niacin [8]. Beetroot contains betalains, nitrogen-containing pigments, which are commonly added to foods as a source of red purple natural color and in addition to great antioxidants, inhibiting cancer cell proliferation and increasing resistance of low-density lipoproteins from oxidation [9]. Dried beetroot can be consumed in the form of chips, as a replacement for potato or corn flakes, rich in trans fatty acids, or after some preparation, also as an ingredient of instant food [10]. Beetroot powder has a natural red colour and can be used as food colouring agent in salads, jams, jellies, deserts, ice creams, beverages and many nutraceutical products and substitute for artificial red colour. The drying of beetroot with the help tray dryer could create high quality powders/slices with minimal loss of betaine and ascorbic acid.

Materials and Methods

Proximate analysis of beetroot

Proximate analysis was carried out before and after drying of beetroot. Fresh beetroot was procured from local vegetable market of Godhra, Panchmahal district. Sound beetroots of uniform size and shape were randomly selected and graded to maintain homogeneity. Diseased, bruised and injured beetroots were discarded. A portable top loading balance (M/s Empire Enterprise, Vadodara) with capacity of 4000 g ± 0.1 g was used for weighing the sample.

Moisture Content, D-3173-73

The initial and final moisture content (MC) of beetroot is determined by drying the known weight of sample in hot air oven at 105 ± 2°C for 24 hours keeping the sample in petri-dish till the constant weight is achieved. The ratio of weight of moisture to the initial weight of the sample is the moisture content on wet basis while the ratio of weight of moisture to the final weight of the sample is the moisture content on dry basis [11].

Ash Content, D-3174-73

Oven-dried sample of beetroot kept in the silica crucible was placed in the muffle furnace at 750 ± 25°C till constant weight is attained.

The ratio of the final weight to the initial weight of the sample is the ash content of the moisture free beetroot sample [11].

Protein Content

Weigh known quantity (0.1 to 0.5 g) sample. Extract with 10 - 50 ml of 0.1N NaOH. Put it in water bath for 6 h at 65°C. After cooling, centrifuge or filter it. Make desirable final volume (10/50ml) with distilled water. Take known aliquot and distilled water of 1ml. Then, add 5 ml of alkaline copper reagent and 0.5 ml of folinciocalteau reagent rapidly and immediately. After 30 minutes, measure the absorbance at 660nm. Draw a standard graph by plotting concentration of the standard on the X- axis versus absorbance on the Y-axis. From the graph, calculate the amount of protein present in the sample tube using following equation [12].

GF = (Concentration of BSA stock solution (g))/(Optical density at 660 nm)

Protein (%) = (GF x OD (Sample Reading)xTotal Volume (ml)x 100x10^{-6}) / (Sample Aliquot (ml) x weight of sample (g))

Fat Content

Fat content in samples is soluble in n-Hexane which was extracted from oven dried sample using a soxhlet extraction apparatus. The method reported by [13] was used for this analysis. The percentage of fat in the sample was calculated as follows:

Fat (%) = (weight of fat (g) x 100)/(weight of sample (g)) (1)

Crude Fiber

Fibra plus instrument (Make: Pelican Equipment, Chennai) was used for estimation of crude fibre. About 2 g of the sample was treated with 1.25 % H_2SO_4 followed by 1.25 % NaOH and washed thoroughly with distilled water after each treatment. Netural residue left over was dried and weighed and then ignited into muffle furnace. From the loss in weight of the residue, the percentage of crude fibre was calculated using following formula given by [14].

Crude fiber (%) = ((W2-W3))/W1 x 100 (2)

Where, W1= Weight of sample + empty crucible, g

W2= Weight of crucible + sample after washing and drying, g

W3= Weight of crucible + ash, g

Total Soluble Solid (TSS)

The total soluble solid was measured using the method reported by Ranganna (1986) [15] for fruits and vegetables. The 10 g sample was weighed in the beaker and 100 ml of distilled water was added. The content of beaker was boiling gently for 2-3 minutes, along with stirring with a glass a rod. The sample was allowed to cool followed by through mixing. After 20 minutes, it was weighed and passed through filter paper. The filtrate was kept for determination. About, 2-3 drops were kept on prism of refractometer and movable prism was adjusted. The reading was noted for determination of TSS. The dilution factor was ($m1/m_0$) multiplied in the observed value. Where, m_0 is mass (g) of the sample before dilution and m1 is the mass (g) of the sample after dilution.

Ascorbic Acid

The ascorbic acid content of the sample was determined by 2, 6- dichlorophenol indophenol visual titration method [15] using the following equation.

Dye factor (mg)=0.5/v (3)

Ascorbic acid (mg⁄100g)=((dye factor×V_2×V_4×100))/((V_1×V_3)) (4)

Where,

v = volume of dye solution required (titre)

V_1 = Volume of sample extract taken for dye titration, ml

V_2 = Volume of the dye require (titre), ml

V_3 = Volume of the sample taken for extraction with HPO_3, ml

V_4 = Volume made up, ml

Carbohydrate

Total carbohydrate content of the sample was estimated by subtracting the measured contents of protein, fat, ash and moisture from 100. The total carbohydrate content was determined using following calculation.

Total carbohydrate (%) = 100 – (protein + fat + ash + moisture) (5)

Betaine Content

The betaine content was measured using Liquid Chromatography Mass Spectrometry and method developed by Food Quality Testing Laboratory (NABL), College of Food Processing Technology and Bio Energy, Anand Agricultural University, Anand.

Slicing of fresh beetroot

An adjustable stainless steel slicer was procured from local market of Godhra. Different slice thickness was maintained using an adjustable knob given beside the slicer. After slicing, different thickness of beetroot was measured using digital vernier caliper.

Tray Dryer

A tray dryer (M/s Nova Instruments Pvt. Ltd., Ahmedabad) having 12 nos. of tray was used for beetroot drying. The drying chamber was constructed from stainless steel with the cavity dimension of 0.86×0.82×0.47 m. The dryer consists of digital micro control based temperature indicator with controller unit, an electric fan and measurement sensors. An air drying temperature in the chamber was measured directly using thermocouple based temperature indicator fixed on the top of tray dryer. Drying was carried out at five level of temperature (55, 60, 65, 70 and 75°C) with different slice thickness (2, 3, 4, 5, and 6 mm) of beetroot. Loss in weight after 30 minutes was recorded till the constant weight is achieved. A portable top loading balance (Capacity: 4000 g ± 0.1 g) was used for measurement of weight of the sample.

Results and Discussion

Proximate analysis of fresh beetroot

The various proximate analysis of fresh beetroot like moisture content, protein content, fat content, carbohydrate, ash content, crude fiber, total soluble solid, ascorbic acid and betaine content were measured according to the methods described in materials and methods section. The proximate analysis of fresh beetroot is shown in [Table-1].

Table-1 *Proximate analysis of fresh beetroot*

SN	Particulars	Average value
1	Moisture content, % (w.b.)	88.94
2	Ash content, %	0.73
3	Protein content, %	0.664
4	Fat content, %	0.21
5	Crude fiber, %	2.50
6	Total Soluble Solid, °Brix	2.60
7	Ascorbic acid, mg/100g	12.33
8	Carbohydrate, %	9.45
9	Betaine, mg/100g	128.07

Drying of beetroot at different drying temperatures and slice thickness

Drying of beetroot was done at different drying temperatures of 55, 60, 65, 70 and 75°C with different slice thickness of 2, 3, 4, 5 and 6 mm using tray dryer. Fresh beetroot slice of different thickness was spread in tray of dryer. Loss in weight was recorded at an interval of 30 minutes.

(i) Drying temperature of 55°C with 2, 3, 4, 5 and 6 mm slice thickness

Initial moisture content of fresh beetroot was 88.94 % (w.b.). The initial weight of all thickness of beetroot slice was 60 g, which reduced to 9.73, 8.90, 11.57, 10.56 and 11.98 g after drying time of 435, 540, 600, 690 and 720 min at slice thickness of 2, 3, 4, 5 and 6 mm with drying temperature of 55°C respectively. The variation in weight loss and drying rate [Fig-1 and 2] was observed with respect to time. The initial drying rate was of the order of 2.11, 1.27, 1.26, 1.18 and 1.16 g water per g dry matter per hour, which reduced to 1.01, 0.86, 0.73, 0.65 and 0.60 g water per g dry matter per hour after 435, 540, 600, 690 and 720 min of drying under tray dryer with 2, 3, 4, 5 and 6 mm slice thickness respectively. The nature of variation of these parameters also indicated that the weight loss and drying rate with respect to time was initially rapid and decreased thereafter in all slice thickness.

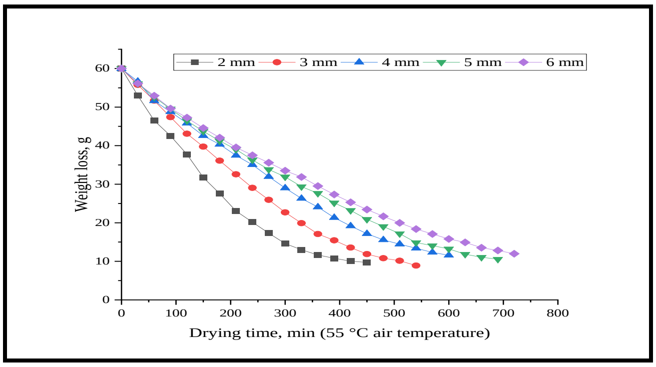

Fig-1 Variation in weight loss with time at 55°C air temperature using tray dryer

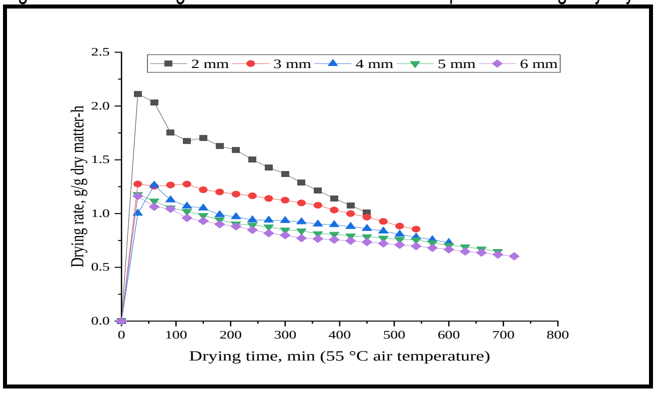

Fig-2 Variation in drying rate with time at 55°C air temperature using tray dryer

(ii) Drying temperature of 60°C with 2, 3, 4, 5 and 6 mm slice thickness

The initial weight of all thickness of beetroot slice was 60 g, which reduced to 9.20, 10.95, 9.73, 8.01 and 9.11 g after drying time of 420, 510, 570, 660 and 690 min at slice thickness of 2, 3, 4, 5 and 6 mm with drying temperature of 60°C respectively. The variation in weight loss and drying rate [Fig-3 and 4] was observed with respect to time. The initial drying rate was of the order of 2.62, 2.30, 1.78, 1.17 and 1.33 g water per g dry matter per hour, which reduced to 1.09, 0.85, 0.80, 0.71 and 0.67 g water per g dry matter per hour after 420, 510, 570, 660 and 690 min of drying under tray dryer with 2, 3, 4, 5 and 6 mm slice thickness respectively.

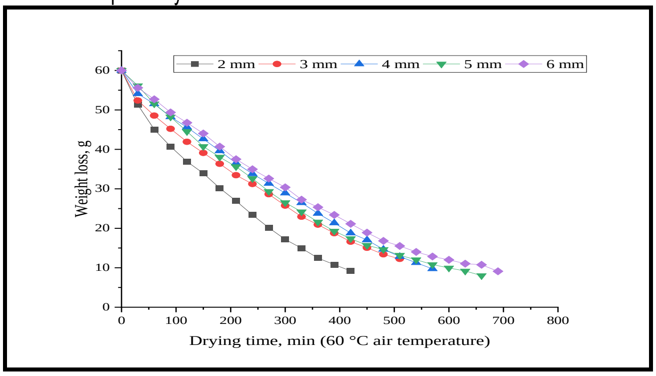

Fig-3 Variation in weight loss with time at 60°C air temperature using tray dryer

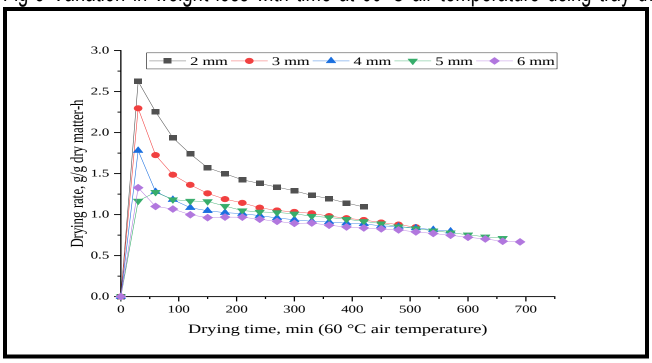

Fig-4 Variation in drying rate with time at 60°C air temperature using tray dryer

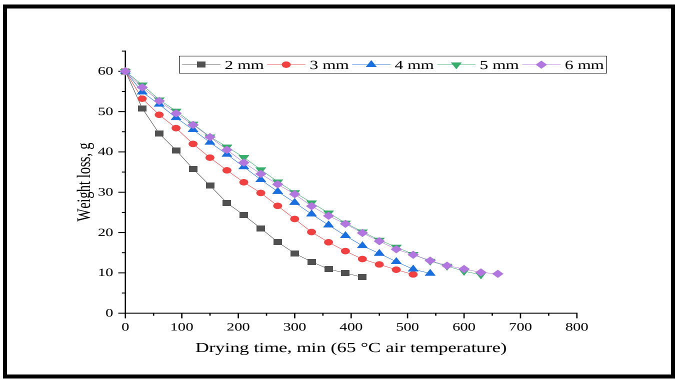

Fig-5 Variation in weight loss with time at 65°C air temperature using tray dryer

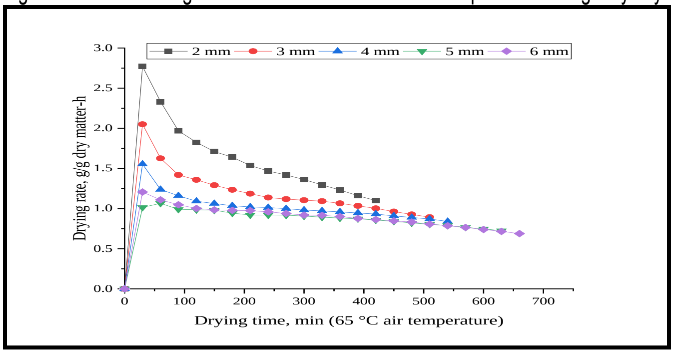

Fig-6 Variation in drying rate with time at 65°C air temperature using tray dryer

(iii) Drying temperature of 65°C with 2, 3, 4, 5 and 6 mm slice thickness

The initial weight of all thickness of beetroot slice was 60 g, which reduced to 8.93, 9.61, 9.86, 9.55 and 9.77 g after drying time of 405, 495, 540, 630 and 660 min at slice thickness of 2, 3, 4, 5 and 6 mm with drying temperature of 65°C respectively. The variation in weight loss and drying rate [Fig-5 and 6] was observed with respect to time. The initial drying rate was of the order of 2.77, 2.05, 1.55, 1.01 and 1.20g water per g dry matter per hour, which reduced to 1.09, 0.89, 0.84, 0.75 and 0.69g water per g dry matter per hour after 405, 495, 540, 630 and 660 min of drying under tray dryer with 2, 3, 4, 5 and 6 mm slice thickness respectively.

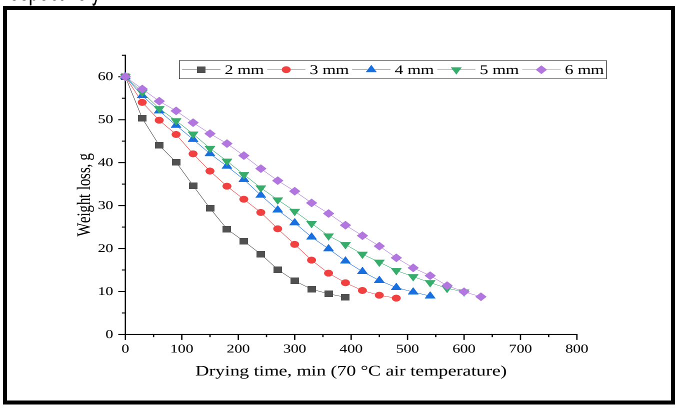

Fig-7 Variation in weight loss with time at 70°C air temperature using tray dryer

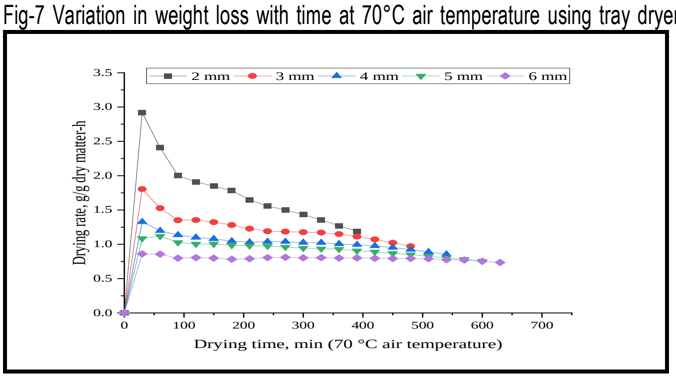

Fig-8 Variation in drying rate with time at 70°C air temperature using tray dryer

(iv) Drying temperature of 70°C with 2, 3, 4, 5 and 6 mm slice thickness
The initial weight of all thickness of beetroot slice was 60 g, which reduced to 8.66, 8.44, 8.94, 9.91 and 8.78 g after drying time of 390, 480, 540, 600 and 630 min at slice thickness of 2, 3, 4, 5 and 6 mm with drying temperature of 70°C respectively. The variation in weight loss and drying rate [Fig-7 and 8] was observed with respect to time. The initial drying rate was of the order of 2.92, 1.80, 1.33, 1.09 and 0.86 g water per g dry matter per hour, which reduced to 1.19, 0.97, 0.86, 0.75 and 0.73 g water per g dry matter per hour after of drying under tray dryer with 2, 3, 4, 5 and 6 mm slice thickness respectively.

(v) Drying temperature of 75°C with 2, 3, 4, 5 and 6 mm slice thickness
The initial weight of all thickness of beetroot slice was 60 g, which reduced to 7.09, 7.90, 8.15, 8.28 and 8.30 g after drying time of 360, 450, 480, 540 and 570 min at slice thickness of 2, 3, 4, 5 and 6 mm with drying temperature of 75°C respectively. The variation in weight loss and drying rate [Fig-9 and 10] was observed with respect to time. The initial drying rate was of the order of 3.01, 2.28, 1.65, 1.61 and 1.71g water per g dry matter per hour, which reduced to 1.33, 1.05, 0.98, 0.87 and 0.82 g water per g dry matter per hour after of drying under tray dryer with 2, 3, 4, 5 and 6 mm slice thickness respectively.

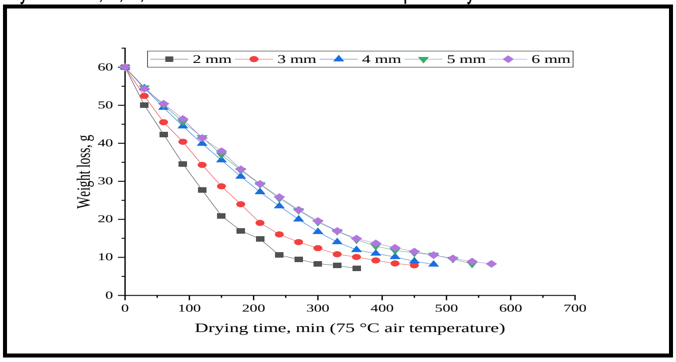

Fig-9 Variation in weight loss with time at 75°C air temperature using tray dryer

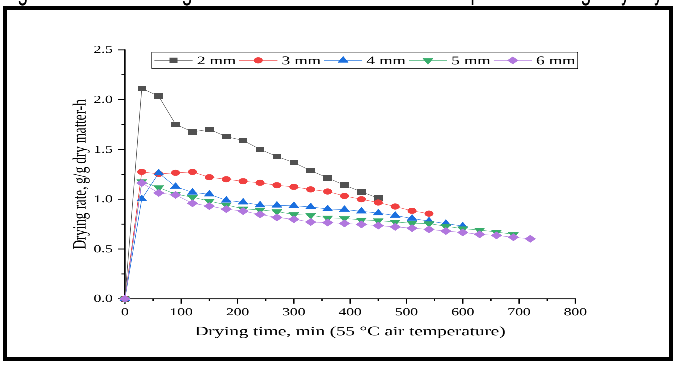

Fig-10 Variation in drying rate with time at 75°C air temperature using tray dryer

Effect of proximate characteristics of dried beetroot using tray dryer
The data obtained in the present investigation was subjected to statistical analysis of variance (ANOVA) technique two factors with replication using completely randomized design (CRD) in Microsoft Excel.

(i) Protein content
The initial protein content was about 0.664 % in fresh beetroot. The maximum value of protein content was found as 2.54 % for the sample dried with 60°C temperature and 2 mm slice thickness, while lowest value was found as 0.50 % for the sample dried with 75°C temperature and 6 mm slice thickness. It can be observed from [Fig-11] that the protein content of beetroot slice during drying significantly decreased with increasing drying temperature and slice thickness. It might be due to higher denaturation of protein at higher temperature and as the increased slice thickness required more time exposure to higher temperature for desired level drying resulting in more loss of protein. A similar result has been reported by Pendre, *et al.*, (2012) [16] in dried okra.
The statistical analysis of the protein content is shown in [Table-2]. It could be seen from the [Table-2] that, as the slice thickness and temperature were increased, the protein content of dried beetroot was found statistically significant on 5 per cent level of significance ($P<0.05$). The interaction between slice thickness and temperature were also found statistically significant on 5 per cent level of significance ($P<0.05$).

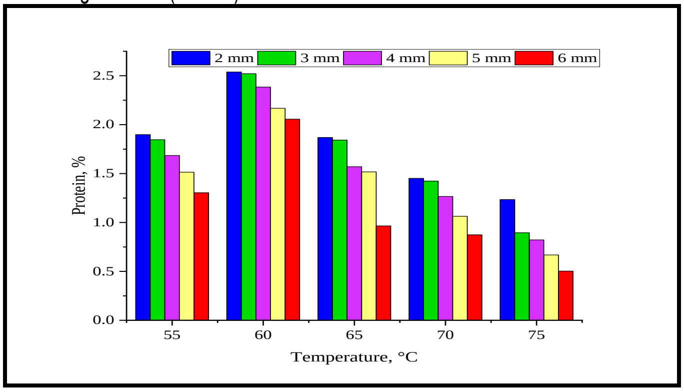

Fig-11 Variation in protein content with temperature at different slice thickness of beetroot using tray dryer

(ii) Fat content
The initial fat content was about 0.21 % in fresh beetroot. The maximum fat content in dried beetroot was found to be 1.88 % in 60°C temperature and 2 mm slice thickness, while minimum fat content of 0.88 % in 75°C temperature and 6 mm slice thickness. It can be observed from [Fig-12] that the fat content of beetroot slice during drying significantly decreased with increasing drying temperature and slice thickness. The lower fat content observed at maximum slice thickness and temperature could be associated with the oxidation of fat during drying. The same result had been also concluded by Fashina, *et al.*, (2017) [17] in dried ground yam. The statistical analysis of the fat content is shown in [Table-3]. It could be seen from the [Table-3] that, as the slice thickness and temperature were increased, the fat content of dried beetroot was found statistically significant on 5 per cent level of significance ($P<0.05$). The interaction between slice thickness and temperature were also found statistically significant on 5 per cent level of significance ($P<0.05$).

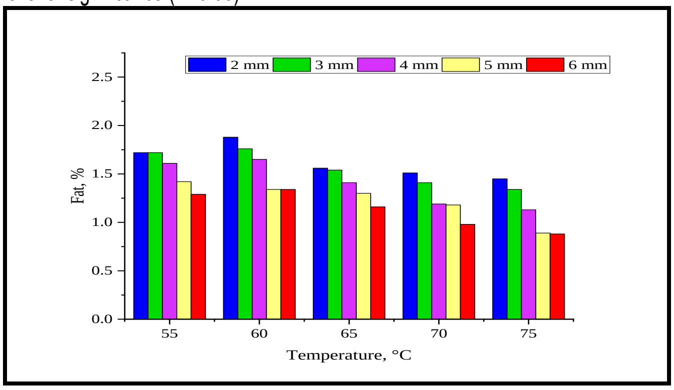

Fig-12 Variation in fat content with temperature at different slice thickness of beetroot using tray dryer

(iii) Carbohydrate
The initial carbohydrate was about 9.45 % in fresh beetroot. The maximum value of carbohydrate was found as 77.80 % for the sample dried with 75°C temperature and 3 mm slice thickness, while lowest value was found as 63.74 % for the sample dried with 60°C temperature and 6 mm slice thickness. It can be observed from [Fig-13] that the carbohydrate of beetroot slice during drying significantly increased with increasing drying temperature while decreased with increasing slice thickness. A similar result has been reported by Fashina, *et al.,* (2017) [17] in dried ground yam. The statistical analysis of the carbohydrate is shown [Table-4]. It could be seen from the [Table-4] that, as the slice thickness and temperature were increased, the carbohydrate of dried beetroot was found statistically significant on 5 per cent level of significance ($P<0.05$). The interaction between slice thickness and temperature were not found statistically significant ($P>0.05$).

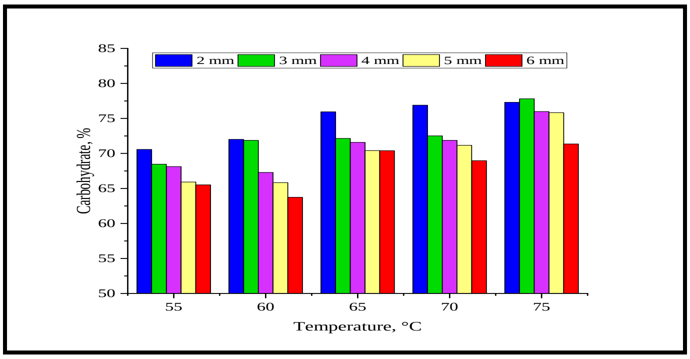

Fig-13 Variation in carbohydrate with temperature at diff. slice thickness of beetroot using tray dryer

(iv) Ash content

The initial ash content was about 0.73 % in fresh beetroot. The maximum ash content in dried beetroot was found to be 10.50 % in 75°C temperature and 6 mm slice thickness, while minimum ash content of 3.87 % in 55°C temperature and 2 mm slice thickness. It can be observed from [Fig-14] that the ash content of beetroot slice during drying significantly increased with increasing drying temperature and slice thickness. The maximum ash content could be as a result of amount of minerals present, increasing the temperature caused the samples to increase in ash content. The same results have been obtained by Adeboye, *et al.*, (2014) [18] during drying of green plantain.

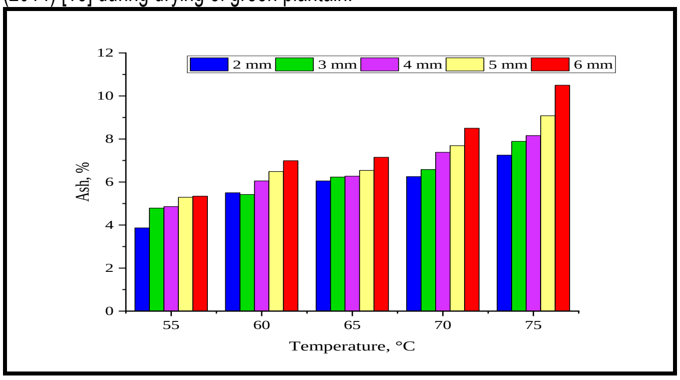

Fig-14 Variation in ash with temperature at different slice thickness of beetroot using tray dryer

The statistical analysis of the ash content is shown in [Table-5]. It could be seen from the [Table-5] that, as the slice thickness and temperature were increased, the ash content of dried beetroot was found statistically significant on 5 per cent level of significance (P<0.05). The interaction between slice thickness and temperature were not found statistically significant (P>0.05).

(v) Crude fiber

The initial crude fiber was about 2.50 % in fresh beetroot. The maximum value of crude fiber was found as 10.72 % for the sample dried with 60°C temperature and 2 mm slice thickness, while lowest value was found as 9.39 % for the sample dried with 75°C temperature and 6 mm slice thickness.

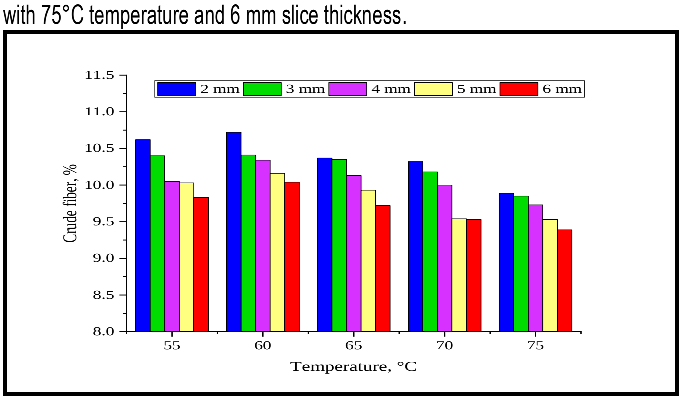

Fig-15 Variation in crude fiber with temperature at different slice thickness of beetroot using tray dryer

It can be observed from [Fig-15] that the crude fiber of beetroot slice during drying significantly decreased with increasing drying temperature and slice thickness. Similar results have been reported by Pendre, *et al.*, (2012) [16] in dried okra. The statistical analysis of the crude fiber is shown in [Table-6]. It could be seen from the [Table-6] that, as the slice thickness and temperature were increased, the crude fiber of dried beetroot was found statistically significant on 5 per cent level of significance (P<0.05). The interaction between slice thickness and temperature were also found statistically significant on 5 per cent level of significance (P<0.05).

(vi)Total soluble solid

The initial total soluble solid was about 2.60 °Brix in fresh beetroot. The maximum total soluble solid in dried beetroot was found to be 8.80 °Brix in 60°C temperature and 6 mm slice thickness [Fig-16], which was significantly higher than those dried at any other combinations. The minimum total soluble solid of 5.07 °Brix in 75°C temperature and 2 mm slice thickness.

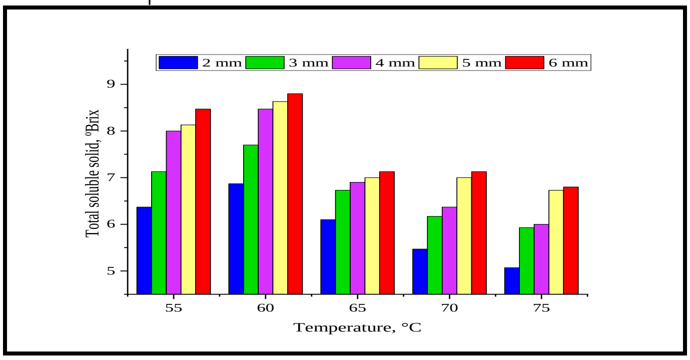

Fig-16- Variation in total soluble solid with temperature at different slice thickness of beetroot using tray dryer

The statistical analysis of the total soluble solid is shown in [Table-7]. It could be seen from the [Table-7] that, as the slice thickness and temperature were increased, the total soluble solid of dried beetroot was found statistically significant on 5 per cent level of significance (P<0.05). The interaction between slice thickness and temperature were also found statistically significant on 5 per cent level of significance (P<0.05).

(vii) Ascorbic acid

The initial ascorbic acid was about 12.33 mg/100g in fresh beetroot. The highest value of ascorbic acid was found as 14.10 mg/100 g for the sample dried with 60°C temperature and 5 mm slice thickness, while lowest value was found as 6.17 mg/100 g for the sample dried with 75°C temperature and 2 mm slice thickness. It can be observed from [Fig-17] that the ascorbic acid of beetroot slice during drying significantly increased with increasing slice thickness while decreased with increasing drying temperature. As the ascorbic acid is highly sensitive towards temperature and rapidly degrade in presence of heat, the samples with more thickness and dried with lower temperature, retained maximum ascorbic acid. Similar trend was found by Gojiya and Vyas (2015) [19] in dried kothimbda.

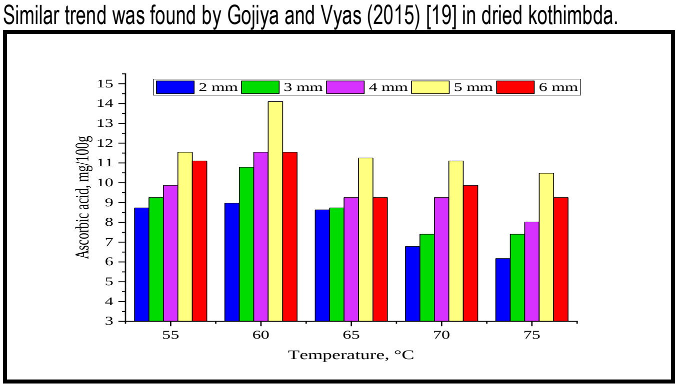

Fig-17 Variation in ascorbic acid with temperature at different slice thickness of beetroot using tray dryer

The statistical analysis of the ascorbic acid is shown in [Table-8]. It could be seen from the [Table-8] that, as the slice thickness and temperature were increased, the ascorbic acid of dried beetroot was found statistically significant on 5 per cent

Table-2 Analysis of variance for protein

Source of Variation	SS	df	MS	F	P-value	$F_{critical}$
Temperature	18.8430	4	4.7107	2427.08	1.42×10^{-56}	2.5572
Slice thickness	4.1154	4	1.0289	530.09	2.93×10^{-40}	2.5572
Interaction	0.3735	16	0.0233	12.03	5.19×10^{-12}	1.8503
Within Groups	0.0970	50	0.0019			
Total	23.4290	74				

Table-3 Analysis of variance for fat

Source of Variation	SS	df	MS	F	P-value	$F_{critical}$
Temperature	2.2460	4	0.5615	1210.15	4.48×10^{-49}	2.5572
Slice thickness	2.6360	4	0.6590	1420.28	8.50×10^{-51}	2.5572
Interaction	0.1757	16	0.0110	23.67	6.85×10^{-18}	1.8503
Within Groups	0.0232	50	0.0005			
Total	5.0810	74				

Table-4 Analysis of variance for carbohydrate

Source of Variation	SS	df	MS	F	P-value	$F_{critical}$
Temperature	648.814	4	162.2035	13.8150	1.17×10^{-07}	2.5572
Slice thickness	378.391	4	94.5977	8.0570	4.29×10^{-05}	2.5572
Interaction	76.688	16	4.7930	0.4082	0.9738	1.8503
Within Groups	587.054	50	11.7411			
Total	1690.948	74				

Table-5 Analysis of variance for ash

Source of Variation	SS	df	MS	F	P-value	$F_{critical}$
Temperature	116.576	4	29.1441	33.3028	1.52×10^{-13}	2.5572
Slice thickness	33.204	4	8.3011	9.4856	8.72×10^{-06}	2.5572
Interaction	7.277	16	0.4548	0.5197	0.9243	1.8503
Within Groups	43.756	50	0.8751			
Total	200.813	74				

Table-6 Analysis of variance for fiber

Source of Variation	SS	df	MS	F	P-value	$F_{critical}$
Temperature	3.9023	4	0.9756	1697.65	1.02×10^{-52}	2.5572
Slice thickness	4.6989	4	1.1747	2044.17	1.01×10^{-54}	2.5572
Interaction	0.4027	16	0.0252	43.79	8.20×10^{-24}	1.8503
Within Groups	0.0287	50	0.0006			
Total	9.0326	74				

Table-7 Analysis of variance for total soluble solid

Source of Variation	SS	df	MS	F	P-value	$F_{critical}$
Temperature	41.3675	4	10.3419	1686.17	1.21×10^{-52}	2.5572
Slice thickness	27.6155	4	6.9039	1125.63	2.68×10^{-48}	2.5572
Interaction	2.3592	16	0.1475	24.04	4.92×10^{-18}	1.8503
Within Groups	0.3067	50	0.0061			
Total	71.6488	74				

Table-8 Analysis of variance for ascorbic acid

Source of Variation	SS	df	MS	F	P-value	$F_{critical}$
Temperature	86.57	4	21.6436	25.43	1.57×10^{-11}	2.5572
Slice thickness	128.59	4	32.1485	37.78	1.53×10^{-14}	2.5572
Interaction	14.08	16	0.8799	1.03	0.4395	1.8503
Within Groups	42.55	50	0.8510			
Total	271.79	74				

Table-9 Analysis of variance for betaine

Source of Variation	SS	df	MS	F	P-value	$F_{critical}$
Temperature	21250.53	4	5312.63	5866.08	4.03×10^{-66}	2.5572
Slice thickness	3730.18	4	932.55	1029.69	2.42×10^{-47}	2.5572
Interaction	4446.34	16	277.90	306.85	3.85×10^{-44}	1.8503
Within Groups	45.28	50	0.91			
Total	29472.34	74				

level of significance (P<0.05). The interaction between slice thickness and temperature were not found statistically significant (P>0.05).

(viii) Betaine content

The initial betaine content was about 128.07 mg/100g in fresh beetroot. The maximum value of betaine content was found as 88.52 mg/100g for the sample dried with 60°C temperature and 5 mm slice thickness, while minimum value was found as 14.94 mg/100gfor the sample dried with 70°C temperature and 6 mm slice thickness. It can be observed from [Fig-18] that the betaine content of beetroot slice during drying significantly increased with increasing slice thickness while decreased with increasing drying temperature.

The statistical analysis of the betaine content is shown in [Table-9]. It could be seen from the [Table-9] that, as the slice thickness and temperature were increased, the betaine content of dried beetroot was found statistically significant on 5 per cent level of significance (P<0.05). The interaction between slice thickness and temperature were also found statistically significant on 5 per cent level of significance (P<0.05).

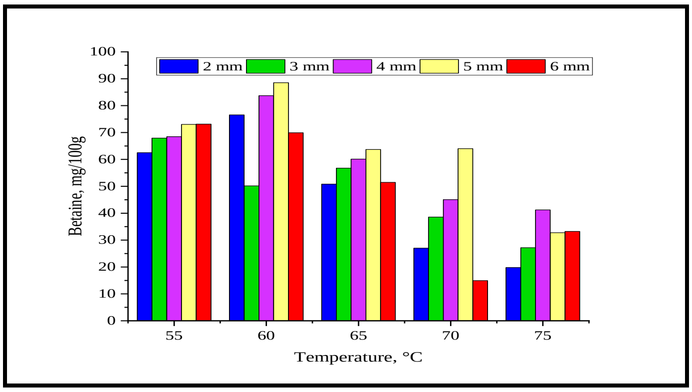

Fig-18 Variation in betaine content with temperature at different slice thickness of beetroot using tray dryer

Conclusion

All the drying can be carried out for thin layer drying of beetroot slices at different drying temperatures and thicknesses, the falling rate drying phenomena was observed. During the initial hours of drying, the drying rate was higher and diminishing with the time of drying. The minimum and maximum drying time of 360 and 720 min was found during 75°C drying temperature with 2 mm slice thickness and 55°C drying temperature with 6 mm slice thickness of dried beetroot respectively. The maximum and minimum average drying rate of 2.08 and 0.80 g water per g dry matter per hour was found during 75°C drying temperature with 2 mm slice thickness and 55°C drying temperature with 6 mm slice thickness of dried beetroot respectively. The maximum and minimum protein content, fat content and crude fiber content of 2.54, 1.88, 10.72 % and 0.50, 0.88, 9.39 % was found during 60°C drying temperature with 2 mm slice thickness and 75°C drying temperature with 6 mm slice thickness of dried beetroot respectively. The maximum and minimum ascorbic acid and betaine content of 14.10 and 88.52 mg/100g and 6.17 and 19.8 mg/100g was found during 60°C drying temperature with 5 mm slice thickness and 75°C drying temperature with 2 mm slice thickness of dried beetroot respectively. The maximum and minimum carbohydrate content of 77.80 and 63.74 % was found during 75°C drying temperature with 3 mm slice thickness and 60°C drying temperature with 6 mm slice thickness of dried beetroot respectively. The maximum and minimum ash content of 10.50 and 3.87 %was found during 75°C drying temperature with 6 mm slice thickness and 55°C drying temperature with 2 mm slice thickness of dried beetroot respectively. The maximum and minimum total soluble solid of 8.80 and 5.07 °Brix was found during 60°C drying temperature with 6 mm slice thickness and 75°C drying temperature with 2 mm slice thickness of dried beetroot respectively.

Application of research: Dried beetroot can be consumed in the form of chips, as a replacement for potato or corn flakes and also as an ingredient of instant food. It can also be used as food coloring agent in salads, jams, jellies, deserts and ice creams *etc.*

Research Category: Processing and Food Engineering

Abbreviations: USDA-United State Department of Agriculture
ASTM-American Society for Testing and Materials
AOAC-Association of Official Agricultural Chemists

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Study area / Sample Collection: Godhra, Panchmahal, Gujarat, India

Cultivar / Variety / Breed name: Beetroot (*Beta vulgaris* L.)

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

References

[1] Anonymous (2018) Farming & gardening. Retrieved from http://www.kishancentral.com/beetroot-growing-information-guide, 10-04-2018.
[2] Muggeridge D.J., Howe C.C., Spendiff O., Pedlar C., James P.E., Easton C. (2014) *Medicine and Science in Sports and Exercise*, 46(1), 143-150.
[3] Stintzing F.C., Carle R. (2004) *Trends in Food Science and Technology*, 15(1), 19-38.
[4] Baysal T., Ic-ier F., Ersus S., Yildiz H. (2003) *European Food Research Technology*, 218, 68-73.
[5] Azharul K.M., Hawlader M.N.A. (2006) *Applied Thermal Engineering*, 26, 121-130.
[6] Waewsak J., Chindaruksa S., Punlek, C. (2006) *Thammasat International Journal of Science and Technology*, 11(1), 14-20.
[7] Doymaz I., Pala M. (2003) *Journal of Food Engineering*, 60(2), 125-130.
[8] U.S. Department of Agriculture (2011) USDA National Nutrient Database for Standard Reference, Retrieved from http://ndb.nal.usda.gov/ (accessed April 09 2018).
[9] Wu L., Hsu H.W., Chen Y.C., Chiu C.C., Lin Y.I., Ho J.A. (2006) *Food Chemistry*, 95(2), 319-327.
[10] Krejcova A., Cernohorsky T., Meixner D. (2007) *Food Chemistry*, 105, 242-247.
[11] ASTM (1983) *Annual book of ASTM Standards. American Society for Testing of Materials. Philadelphia, PA*, 19103.
[12] Lowry O.H., Rosebrough N.J., Farr A.L., Randall, R.J. (1951) *J.Biol.Chem.*, 193, 265.
[13] AOAC (2000) *Official methods of analysis: Association of Official Analytical Chemists International. Maryland, USA*.
[14] Ranganna S. (2007) *Handbook of analysis and quality control for fruit and vegetable products. 2nd Edn. Tata McGraw Hill Co. Ltd., New Delhi, India.*
[15] Ranganna S. (1986) *Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill Education, New Delhi, India*, 124-125.
[16] Pendre N.K., Nema P.K., Sharma H.P., Rathore S.S., Kushwah S.S. (2012) *J Food Sci Technol.*, 49(3), 378–381.
[17] Fashina A.B., Adejori E.A., Akande F.B. (2017) *International Food Research Journal*, 24(3), 1349-1352.
[18] Adeboye O.A., Iyanda R.A., Yusuf K.A., Olaniyan A.M., Oje K.O. (2014) *International Journal of Technology Enhancement and Emerging Engineering Research*, 2(7), 92-99.
[19] Gojiya D.K., Vyas D.M. (2015) *Journal of Food Processing & Technology*, 6(1), 1-8.