Effect of different drying methods on quality attributes of beetroot (*Beta vulgaris*) slices

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Abstract

Purpose – The purpose of this paper is to evaluate the effect of different drying methods on quality attributes of beetroot slices.

Design/methodology/approach – Three drying methods (sun, oven and freeze-drying) were applied to dry fresh slices of beetroot cultivar (*Beta vulgaris*). The chemical composition, minerals, nitrate, betalains, total phenolic, total flavonoid and color were measured for fresh and dried slices.

Findings – The chemical composition, minerals, nitrate, bioactive compounds and color were measured for fresh and dried slices. Regardless of the drying method, the results showed that the chemical composition, total energy, minerals and nitrate of the dried slices were significantly ($p = 0.05$) increased compared to that of fresh slices. Sun and oven drying of the slices significantly ($p = 0.05$) reduced total betalain and betacynin. However, betaxanthin was significantly ($p = 0.05$) increased. Total phenolics content of fresh beetroot was significantly ($p = 0.05$) increased after sun and oven drying but total flavonoids were decreased. The 2,2,-diphenyl-2-picryl-hydrazyl (DPPH) of fresh beetroot was increased significantly ($p = 0.05$) after sun and oven drying. The measurement of the color of the powder showed that there is a decrease in lightness (L) depending on the drying method applied. A maximum reduction in lightness was observed in powder of sun-dried slices. The color of the powder obtained from freeze-dried slices was stable compared to other drying methods.

Practical implications – Beetroot is a rich source of nutrients but with short shelf life. Dried beetroot has more keeping quality than the fresh one.

Originality/value – The study uses beetroot as a rich source of nutrients as well as natural antioxidant source. Betalain compounds are preserved in beetroot and a high source of phenolics and flavonoids. Flavonoids are a group of phenolic products of plant metabolism with high antioxidant properties to protect against diseases without side effects.

Keywords Minerals, Colour, Drying, Bioactive compounds, Beetroot

Paper type Research paper

Introduction

The beneficial effects derived from diets rich in fruits and vegetables is to protect against the risks for chronic angiogenic diseases, such as cardiovascular diseases, arthritis, chronic inflammation and cancers (Saleem *et al.*, 2002). Among the known fruits and vegetables, deep-colored fruits and vegetables have been reported to be good sources of phenolics, including flavonoids, anthocyanins and carotenoids and recognized as more healthy to human body, especially in the oriental countries (Sass-Kiss *et al.*, 2005). Several deep-colored vegetables such as tomato, carrot, eggplant and red beetroot have been reported to contain large amounts of bioactive compounds and have strong antioxidant capacity (Babiker and Eltoum, 2014).

Beetroot (*Beta vulgaris*) as a flavoring agent is a member of the chenopodiaceous family, which includes silver beet, sugar beet, beet and fodder beet (Grubben and Denton, 2004). They are biennials although they are usually grown as annuals and believed to have originated from Germany (Thompson, 2001). Beetroot produces green tops and a swollen root during growing season. It is usually grown for salad and extraction of sugar from the roots. The balls are round and small with thin red-brown skin and notably sweet flavor. It can be cooked, blanched, steamed or boiled whole with some greens left intact.

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Beetroot is one of the richest dietary sources of antioxidants and naturally occurring nitrates (Maheswari *et al.*, 2013). The nitrates in beetroot improve the blood flow through the body including the brain, heart and muscles. It increases a molecule in the blood vessels called nitric oxide which helps open up the vessels and allows more oxygen flow; it also lowers blood pressure and decreases the incidence of cardiovascular disease (Kenjale and Ham, 2011). A number of studies have reported beetroot as a dietary inorganic nitrate with a potential for reducing blood pressure in humans (Bailey *et al.*, 2009). Consumption of beetroot juice on a low nitrate diet, it may lower blood pressure and therefore reduce the risk of cardiovascular event (Coles and Clifton, 2012).

Along with the consumption of fresh vegetables, the dried vegetable including dried powders of vegetables have been used to produce the deep-colored foods, such as tomato ketchup, carrot powder, cakes, functional foods (Kendall and Allen, 2006). Drying methods play an important role in the production of dried vegetables; however, during drying process the bioactive compounds and their antioxidant capacity might be lost (Kendall and Allen, 2006). Fresh beetroots are exposed to spoilage due to their high moisture content. One of the preservation methods ensuring microbial safety of biological products is drying (Mathlouthi, 2001).

Dried beetroots can be consumed directly in the form of chips as a substitute of traditional snacks that are rich in fatty acids, or after easy preparation as a component of instant food (Krejcova *et al.*, 2007). The drying technique has been proven to change the chemical composition of plant foods, such as fruits, vegetables and increase their storage stability and shelf life (Akpapunam, 2007). Various plant vegetables (beetroot and Moringa leaves) undergo different drying methods, such as sun drying, oven and shade drying (Akpapunam, 2007). The objective of the study is to evaluate the effect of different drying methods (sun-, oven- and freeze-drying) on chemical, minerals and nitrate compositions, bioactive compounds and color characteristics of beetroot slices.

Materials and methods

Samples preparation

Beetroots (*Beta vulgaris*) were purchased from the vegetable market, Khartoum North, Shambat, Sudan. Damaged fruits and those with defects were discarded. The Beetroot was washed to remove sand, dirt, debris and peeled. The peeled beetroots were then sliced into 2 mm slices. For sun drying, stainless steel trays were placed on the roof of a room closed to the department laboratory and exposed to direct sunlight for about three days (31-48°C, 20-25 percent RH). The slices were turned upside down several times during the drying period to ensure equal exposure to sunlight and to prevent sticking of the material to the trays. Dry layer with plastic texture when touched by hands and the general appearance was used to determine the end of the drying process. For oven drying, the slices were placed in stainless steel trays and dried to constant weight at 70 ± 2.0°C for 24 hours. For freeze-drying process, sliced product was subsequently placed into freeze-drying trays at a depth of 0.5 inches and frozen to ca. −23°C. Then frozen trays were loaded into a commercial freeze-dryer (Virtis Company, Gardner, New York), at the National Research Center, Khartoum, Sudan, and dried for 24 h. The vacuum pressure during the drying cycle was within a range of 0.5 – 1.0 mm Hg. Dried samples were then ground to pass a 0.40 mm mesh powder using a hammer mill.

Analysis. Chemical composition. The chemical composition of the samples was determined according to AOAC (2003).

Determination of total energy. The total energy was calculated using Atwater factors:

$$\text{Energy value} = \text{Protein}\,(\%) \times 4 + \text{Carbohydrate}\,(\%) \times 4 + \text{Fat}\,(\%) \times 9$$

Determination of total minerals. Minerals were extracted from the samples by the dry ashing method described by Chapman and Pratt (1982). About 2.0 g of sample was acid-digested with

diacid mixture (HNO_3:$HClO_4$, 5:1, v/v) in a digestion chamber. The digested samples were dissolved in double-distilled water and filtered (Whatman No. 42). The filtrate was made to 50 mL with double-distilled water and was used for determination of potassium, calcium, magnesium, phosphorus and iron. Elements (K, Mg and Fe) were determined by atomic absorption spectrophotometer (Perkin Elmer 2380 Atomic Spectrometer AT). Calcium was determined by a titration method. Phosphorus was determined spectrophotometrically using molybdovanadate method.

Determination of nitrate. In total, 50 mg of sample was selected and deionized water was added to the samples (nine times than exact the sample weight) and the water and sub-sample were homogenized for 15 minutes. About 30 gram sample of homogenate was placed in a centrifuge tube, and 0.5 ml of H_2O_2 was added and the tube was capped and homogenized well by the hand after addition of H_2O_2. All samples were centrifuged at 3500 rpm for 3 min. The supernatant was then separated and filtered with filter paper Whatman No. 1 and nitrate concentration in the filtrate was determined calorimetrically by a flow injection analysis system (AOAC, 2003). The nitrate content was expressed as mg nitrate per 100 gm on a dry weight basis (mg NO_3/100 gm DW). To prevent the changes in nitrate concentrations after the extracts, the extracted solution immediately were measured.

Determination of betalains compounds. About 0.1 gm of the samples were dissolved in 10 ml of 50 percent ethanol, were agitated for 10 s and the homogenate was centrifuged at 6000 rpm for 10 min. The supernatant was collected as it is after centrifugation and the same was repeated for two more times to ensure maximum extraction of betalains. The supernatant was further used for determination of betalains. The content of betaxanthins and betacyanins in the extracts was determined spectrophotometrically at 538 nm and 480 nm with a UV-Vis spectrometer, respectively, according to the methods of Stintzing and Carle (2004). The absorbance reading obtained was used to calculate the betalain concentration for each sample. Total betalains were the sum of both betacyanins and betaxhantins. The results were expressed as mg of total betalains per gm dry weight.

Total phenolic content Determination. A content of total phenolics was determined using the Folin-Ciocalteu's colorimetric method as previously reported by Hung and Morita (2008). Extracted solution (0.5 ml) was put into a test tube and the Folin-Ciocalteu's phenolic reagent (0.5 ml) was added. The content was vortex mixed and added with 1 ml of saturated sodium carbonate solution, followed by adjusting the volume to 10 ml with distilled water. The mixtures in the tubes were thoroughly mixed by vortexing. Tubes were allowed to stand at ambient temperature for 10 min until the characteristic blue color developed. The control was prepared in the same way but the extracted solution was replaced by methanol (0.5 ml). Absorbance of the clear supernatants was measured at 725 nm using a spectrophotometer (UVD-2960, Labomed, Inc.). Gallic acid was used as a standard and total phenolic content were calculated and expressed as mg Gallic acid equivalent per gm sample. All analyses were performed in triplicate.

Total flavonoids determination. The total flavonoids content of tomato extracts was determined using a modified colorimetric method described by Zhishen *et al.* (1999). Both the methanolic extract (250 μL) and (+)−catechin standard solutions were mixed, respectively, with 1.25 ml distilled water and 75 μL of 5 percent $NaNO_2$ solution, then allowed to stand for 6 min. Thereafter, 150 μL of 10 percent $AlCl_3$ solution was added and mixed for 5 min. Then, 0.5 ml of 1.0 M NaOH was added and the total volume was made up to 2.5 ml with distilled water. The absorbance was measured at 510 nm against a prepared blank using UV/Vis spectrophotometer Model 4050 (LKB Biochrom, Cambridge, England).

2,2,-diphenyl-2-picryl-hydrazyl (DPPH) scavenging capacity determination. Free radical scavenging activity (RSA) of the samples was determined using DPPH according to Turkmen *et al.* (2005) method with slight modifications. Different dilutions of the extracts

were prepared in triplicate. An aliquot of 2 ml of 0.15 mM DPPH radical in ethanol was added to a test tube with 1 ml of the sample extract. The reaction mixture was vortex mixed for 30 s and left to stand at room temperature in the dark for 20 min. The absorbance was measured at 517 nm using a spectrophotometer (Spectronic20 GenesysTM, Illinois, USA). The control consisted of 1 ml of distilled water in 2 ml of the DPPH solution and the free RSA was calculated as percentage using the following equation:

$$\text{RSA } \% = \frac{A_0 - A_1}{A_0} \times 100$$

where, A_0 is the absorbance of the control and A_1 is the absorbance of the sample extract.

Color measurement. The color (L, a and b) of treated and untreated samples was measured with a Hunter Lab colourimeter (Model No. Miniscan® XE plus 4500 L, Hunter Associates Laboratory, Inc., VA, USA). The instrument (45°/0° geometry, D 65 optical sensor, 10° observer) was calibrated with black and white reference tiles through the tri-stimulus values X, Y and Z, taking as standard values those of the white background tile. Beetroot slices were scanned at three different locations to determine the average L, a and b values during the measurements. Total color difference (ΔE) and browning index (BI) which indicates the magnitude of color change after treatment was calculated using the following equations (Palou *et al.*, 1999):

$$\Delta E = \left\{ (L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2 \right\}^{0.5} \quad (1)$$

where L, a, b are the measured values of original samples and L_0, a_0, b_0 are the values of treated beetroot at the start of experiment:

$$\text{Browning index } (BI) = [100(X - 0.31)]\, 10.72 \quad (2)$$

where, $X = (a + 1.75\,L)/(5.645\,L + a - 3.012b)$.

Statistical analysis. Each determination was carried out on three separate samples and analyzed in triplicate on fresh weight basis; the figures were then averaged. Data were assessed by the analysis of variance (ANOVA) described by Snedecor and Cochran (1987). Comparisons of means for treatments were made using Duncan's multiple range tests. Significance was accepted at $p \leqslant 0.05$.

Results and discussion

Effect of different drying methods on chemical composition of beetroot slices

Table I shows the effect of different drying methods on chemical composition of beetroot slices. The drying process (sun, oven and freeze) was carried out to a constant weight in all methods; therefore, the dry matter content variation among drying methods was observed to be significant ($p \geqslant 0.05$) for slices. The dry matter of the fresh slices was increased

Sample	Chemical composition						
	Dry matter	Ash	Protein	Fiber	Oil	Carbohydrates	Total energy
Fresh	12.32 ± 0.09^{d}	2.02 ± 0.08^{b}	1.52 ± 0.13^{b}	2.81 ± 0.57^{c}	0.17 ± 0.03^{b}	5.80 ± 0.21^{d}	30.81 ± 1.31^{d}
Sun-dried	75.62 ± 0.12^{c}	3.65 ± 0.42^{a}	3.53 ± 0.32^{a}	6.61 ± 0.19^{a}	0.30 ± 0.07^{a}	61.53 ± 0.78^{c}	262.94 ± 2.13^{c}
Oven-dried	80.30 ± 0.72^{b}	2.96 ± 0.27^{b}	3.01 ± 0.51^{a}	6.73 ± 0.24^{a}	0.45 ± 0.02^{a}	67.15 ± 0.89^{b}	284.69 ± 1.81^{b}
Freeze-dried	82.84 ± 0.81^{a}	3.89 ± 0.62^{a}	3.89 ± 0.46^{a}	5.01 ± 0.48^{b}	0.51 ± 0.09^{a}	69.54 ± 0.63^{a}	298.31 ± 2.01^{a}

Notes: Values are means ± SD of triplicate samples. Means with different superscript letter in a column are significantly different at $p \geqslant 0.05$

Table I.
Chemical composition (%) and total energy (Kcal) of fresh and dried beetroot slices

significantly ($p \geq 0.05$) when the slices were dried using sun, oven and freeze-drying. The increase in the dry matter is due to removal of slices moisture. The results showed that the moisture content was higher in the fresh beetroot slices than in dried ones. The high moisture content in the fresh vegetables is expected since it has been reported that vegetables in their fresh state contain basically 85 percent water (Kendall and Allen, 2006). The lower water content of dried vegetables is not surprising since Ukegbu and Okereke (2013) reported that drying involves lowering the amount of water to below 1–55 percent in vegetables. The moisture content of a food is very important on nutrient density and shelf life of that particular food. The moisture content of the dried beetroot slices can be said to be within the acceptable moisture level for dried vegetables.

The ash content of the fresh slices dried by freeze have significantly ($p \geq 0.05$) higher ash content (3.82 percent) than that dried by oven (2.96 percent), but slightly higher than that dried by sun (3.65 percent) and the difference was not significant. The ash content of beetroot slices was significantly ($p \geq 0.05$) higher when dried by freeze than that dried by sun or oven. The results revealed that drying concentrated the constituents of the sample and increased the ash content. The results of the present study supported the report of Onwuka *et al.* (2002) who observed an increase in the ash content of dried vegetables. Drying significantly ($p \geq 0.05$) increased the ash content because the removal of moisture, according to Morris *et al.* (2004) leads to an increase in concentration of nutrients.

The results showed that the crude protein of fresh slices was significantly ($p \geq 0.05$) increased due to drying. However, a marginal difference in crude protein between the drying methods was observed. The crude protein of the slices dried by freeze-drying (3.89 percent) was slightly higher than that of the slices dried by sun and oven. Similar observation was made by Ukegbu and Okereke (2013) on the protein content; they observed an increase in protein content of sun-dried vegetables compared to fresh samples which may occur as a result of loss of moisture which in turn has an influence on dry matter.

The slices dried by sun or oven had fiber content significantly ($p \geq 0.05$) higher than that of the fresh ones and that obtained by freeze-drying. However, the difference in fiber content between the drying methods is not significant. Ukegbu and Okereke (2013) studied the effect of drying on vegetables and showed that drying increased the fiber content of the vegetables depending on the drying time and temperature. The increment in fiber content, in general, could be attributed to the loss of other constituents.

No significant difference ($p \geq 0.05$) was observed in oil content of fresh or dried by different methods. Slices dried by sun, oven and freeze recorded higher oil content than that of fresh (0.17 percent). A slight variation was observed between the drying methods. Similarly Ukegbu and Okereke (2013) reported that the oil content of dried vegetables was higher compared to fresh samples which may occur as a result of loss of moisture which in turn has an influence on dry matter.

The carbohydrate content was significantly ($p \geq 0.05$) higher under freeze-drying than sun or oven drying. However, both sun and oven drying significantly ($p \geq 0.05$) increased carbohydrate content compared to that of fresh slices. Vegetables in their fresh state have been noted to be poor sources of carbohydrate. However, after drying, the carbohydrate content of vegetables will increase (Kolawole *et al.*, 2011). Low level of carbohydrate in vegetables showed that they supply little or no energy when consumed except when supplemented with other foods. It was observed that freeze-drying had higher values for chemical composition, this mainly due to the fact that freeze-drying is the drying method that gives final products of the highest quality compared to other drying methods.

The total energy was significantly ($p \geq 0.05$) higher under freeze-drying (298.31 Kcal) than sun (262.94 Kcal) or oven (284.69 Kcal) drying. However, both sun and oven drying significantly ($p \geq 0.05$) increased the total energy compared to that of fresh slices. The low caloric values obtained in this study could be explained to low proteins, lipids and total

carbohydrate contents especially for fresh slices. The results of the present study agree with those reported by Constant *et al.* (2016) who studied the effect of sun drying on nutritive and antioxidant properties of five leafy vegetables consumed in Southern Cote Divoire.

Effect of different drying methods on some minerals and nitrate composition of beetroot slices

Table II shows the minerals (K, Ca, Mg, P and Fe) and nitrate contents of fresh and dried beetroot slices. The potassium content of fresh slices significantly ($p \geq 0.05$) increased after drying to when the slices were dried by sun, oven or freeze-drying. It was observed that freeze-dried slices had significantly higher ($p \geq 0.05$) potassium content than sun or oven-dried ones. However, sun-dried slices had significantly higher ($p \geq 0.05$) potassium content than oven-dried which indicated that potassium is sensitive to heat. The high potassium content of the dried vegetables may be an advantage since it can be used for therapy (Okoli, 2009). The dietary potassium may play a role in decreasing blood pressure. Potassium is involved in nerve function muscle control and blood pressure. Increasing potassium in the diet may protect against hypertension in people who are sensitive to high levels of sodium (Okoli, 2009).

The calcium content of fresh slices was increased significantly ($p \geq 0.05$) after drying. It was observed that freeze-dried slices had significantly higher ($p \geq 0.05$) calcium content than sun-dried ones. Similarly, Negi and Roys (2001) reported that the calcium content of dried vegetables is higher than that of fresh vegetables. Calcium is an essential mineral for proper growth and maintenance of the body, it helps to build and maintain healthy life.

The results showed that the magnesium content of freeze-dried slices was significantly higher ($p \geq 0.05$) than fresh, sun- or oven-dried slices. This indicates that freeze-dried beetroot slices contained more magnesium than fresh and dried slices. David and Whitefield (2000) also reported that the dried vegetables had higher magnesium and this also may be attributed to the controlled temperature during the drying process.

The phosphorus content was significantly ($p \geq 0.05$) higher in dried slices compared to fresh ones. However, no significant difference was observed between the dried methods in phosphorus content. Similarly, Negi and Roys (2001) reported higher phosphorus content of dried vegetables than fresh ones. This may be attributed to the controlled and relatively higher temperature of the drier during the drying process (Kendall and Allen, 2006).

The iron content was significantly ($p \geq 0.05$) higher in dried slices compared to fresh ones. A significant variation was observed between the dried methods in Fe content with higher value obtained when the slices were dried by freeze-drying. The results indicated that drying significantly ($p \geq 0.05$) improved Fe content. Similar result of increment in Fe as a result of drying was reported by Joshi and Mehta who studied the effect of dehydration on the nutritive value of drumstick leaves.

As shown in Table II, the nitrate content of fresh slices was significantly ($p \geq 0.05$) increased after drying. It was observed that freeze-dried slices had significantly higher ($p \geq 0.05$) nitrate content than sun or oven-dried ones. Beetroot is one of the richest dietary

Table II.
Minerals and nitrate contents (mg/100 g dry weight basis) of fresh and dried beetroot slices

Sample	Minerals					
	K	Ca	Mg	P	Fe	Nitrate
Fresh	259.91 ± 3.05^{d}	2.15 ± 0.48^{c}	21.81 ± 0.39^{c}	7.07 ± 0.59^{b}	140.11 ± 0.64^{d}	197.67 ± 1.23^{d}
Sun-dried	291.09 ± 2.89^{b}	4.13 ± 0.31^{b}	29.67 ± 0.26^{b}	8.13 ± 0.72^{a}	152.19 ± 0.88^{c}	251.08 ± 0.83^{c}
Oven-dried	281.87 ± 1.88^{c}	4.98 ± 0.71^{ba}	31.67 ± 0.57^{a}	8.67 ± 0.66^{a}	153.99 ± 0.79^{b}	256.87 ± 0.57^{b}
Freeze-dried	295.97 ± 2.08^{a}	5.23 ± 0.26^{a}	32.86 ± 0.99^{a}	8.97 ± 0.75^{a}	161.89 ± 0.89^{a}	261.09 ± 0.38^{a}

Notes: Values are means $\pm$ SD of triplicate samples. Means with different superscript letter in a column are significantly different at $p \geq 0.05$

sources of antioxidants and naturally occurring nitrates (Maheswari *et al.*, 2013). The nitrates in beetroot improve blood flow through the body including the brain, heart and muscles. It increases a molecule in the blood vessels called nitric oxide which helps open up the vessels and allows more oxygen flow; it also lowers blood pressure and decreases the incidence of cardiovascular disease (Kenjale and Ham, 2011). A number of studies have reported beetroot as a dietary inorganic nitrate with a potential for reducing blood pressure in humans (Bailey *et al.*, 2009).

Effect of different drying methods on bioactive compounds of beetroot slices

Effect of different drying methods on betalains contents. Table III shows the effect of different drying methods on bioactive compounds of beetroot slices. Sun and oven drying of the slices significantly ($p \geq 0.05$) reduced total betalain and betacynin but freeze-drying did not have a significant effect on betalain and betacynin contents. However, betaxanthin was significantly ($p \geq 0.05$) increased when the slices were dried by sun and oven. Betalains are water-soluble, nitrogen-containing natural pigments, which can be divided into two groups: red-violet betacyanins and yellow-orange betaxanthins (Ravichandran *et al.*, 2013). As shown in Table III, betalains significantly ($p \geq 0.05$) decreased as a consequence of the drying (except freeze-drying), which is in agreement with previous research showing the sensitivity of these compounds toward high temperature (Herbach *et al.*, 2006 and Ravichandran *et al.*, 2013). It has been reported that the thermal stability of betalains depends on numerous physicochemical conditions of which heating conditions are the most important factors (Herbach *et al.*, 2006). Kowalski and Szadzinska (2014) reported that betalains are highly sensitive to light, heat and oxygen. Gokhale and Lele (2014) reported that betalain content and antioxidant activity of whole beet powder depends on drying temperature. Betacyanin decreased whereas betaxanthin increased with increase in drying temperature from 50 to 120°C (Gokhale and Lele, 2014). Thus, betacyanin was found to be more temperature sensitive than betaxanthin. Moreover, Ravichandran *et al.*, (2013) observed that an increase in drying temperature decreases betacyanin (red pigment) and increases betaxanthin (yellow pigment), it was thought that at increased temperature, betacyanin was getting converted to betaxanthin. However, in this paper, freeze-drying was observed to be an ideal method of drying due to the fact that drying using such method implies low temperature.

Effect of different drying methods on total phenolics and flavonoids. As shown in Table III total phenolics of fresh beetroot was significantly ($p \geq 0.05$) increased after sun and oven drying. However, freeze-drying did not have a significant effect on total phenolics. The results obtained for total phenolics in this study indicated that application of temperature during drying significantly increased the total phenolics of beetroot which agree with Oboh and Akindahunsi (2004) who reported that sun drying of green leafy vegetables caused a significant increase in total phenolic contents. Another investigation by

	Bioactive compounds					
Sample	Total betalain mg/100 gm	β-cyanin mg/ 100gm	β-xanthin mg/ 100 gm	Total phenolics (mg GAE/gm)	Total flavonoids (mg RE/gm)	DPPH (%)
Fresh	115.34 ± 1.09^{b}	82.67 ± 0.34^{a}	32.67 ± 0.68^{c}	29.66 ± 0.83^{c}	36.37 ± 0.87^{a}	12.58 ± 0.27^{d}
Sun-dried	113.30 ± 0.89^{a}	69.04 ± 0.74^{b}	44.26 ± 0.49^{b}	34.85 ± 0.73^{b}	34.74 ± 0.54^{b}	21.95 ± 0.31^{b}
Oven-dried	113.26 ± 1.02^{b}	60.46 ± 0.29^{c}	52.81 ± 0.91^{a}	39.56 ± 0.95^{a}	33.28 ± 0.72^{b}	24.60 ± 0.45^{a}
Freeze-dried	114.51 ± 0.79^{b}	82.19 ± 0.54^{a}	32.23 ± 0.57^{c}	30.19 ± 0.79^{c}	36.11 ± 0.95^{a}	14.18 ± 0.29^{c}

Notes: Values are means ± SD of triplicate samples. Means with different superscript letter in a column are significantly different at $p \geq 0.05$

Table III. Effect of drying methods on bioactive compounds contents and antioxidant activity (DPPH) of beetroot slices

Capecka *et al.* (2005) reported that air drying resulted in a considerable increase in total phenolic contents of oregano and peppermint leaves, but no significant difference was observed for lemon balm. Probably, food processes might accelerate the release of more bound phenolic compounds that are released due to the breakdown of cellular constituents.

Total flavonoid of fresh beetroot was significantly ($p \geq 0.05$) decreased when the slices were dried by both sun and oven (Table III). However, freeze-drying had no significant effect on total flavonoid. The results obtained for flavonoids after drying of beetroot slices indicated that heat had an adverse effect on flavonoids of beetroot which agree with Mohd-Zainol *et al.* (2009) who studied the effect of different drying methods (freeze-dried, vacuum oven and air oven) on the degradation of flavonoids in Centella asiatica. The results of the study showed that destruction of flavonoids varied with the different drying treatments undergone by the samples. Mohd-Zainol *et al.* (2009) reported that the loss of flavonoid was found to be the least in freeze-dried samples, followed by vacuum dried samples and finally oven-dried samples. The result is probably due to the temperature and time used in the drying methods. Accordingly, the loss of macromolecules like flavonoid during heat treatment might be due to the harsh drying conditions, in particular, the temperature and duration used. Similarly, Davey *et al.* (2000) reported that wet thermal processing can affect the phytochemicals by thermal breakdown that affect the integrity of the cell structure which then resulted in the migration of components, leading to losses by leakage or breakdown by various chemical reactions involving enzymes, light and oxygen.

Effect of different drying methods on DPPH during drying. As shown in Table III, the DPPH of fresh beetroot was increased significantly ($p \geq 0.05$) after sun and oven drying. The results obtained for DPPH indicated that heat treatment of the slices significantly increased the antioxidant activity of the slices due to increased level of total phenolics and betaxanthin which agree with the report of Oboh and Akindahunsi (2004) who observed that sun drying caused a significant ($p \geq 0.05$) increase in the antioxidant properties of the green leafy vegetables. Also Kavitha *et al.* (2013) reported that the antioxidant capacity depends on the presence of betalains and polyphenols, which is increased after thermal treatment. Betalains and anthocyanins are mutually exclusive in their natural occurrence, but phenolics and flavonoids have also been found in different beetroot materials (Kujala *et al.*, 2000), contributing to the strong antioxidant activity of beetroot extract. It was also seen that increase in drying temperature results in increase in total phenolic content and antioxidant activity. This showed that betaxanthin has more antioxidant activity than betacyanin (Kujala *et al.*, 2000).

Effect of different drying methods on color characteristics of dried beetroot slices. Table IV shows the effect of different drying methods on color characteristics of dried powder of beetroot slices. The measurement of color of beetroot powder on Hunter Lab scale showed that there is a decrease in lightness (L) depending on the drying technique applied. A maximum reduction in lightness was observed in powder of sun-dried slices. The lightness of powder prepared from freeze-dried slices was observed to be stable

	Color attributes					
Sample	Lightness (L)	Redness (a)	Yellowness (b)	a/b	Total color difference (ΔE)	Browning index (BI)
Fresh	24.74 ± 0.69^{a}	22.19 ± 0.38^{a}	2.32 ± 0.78^{b}	9.56 ± 0.33^{a}	–	121.36 ± 0.31^{b}
Sun-dried	22.01 ± 0.42^{b}	18.26 ± 0.61^{b}	3.09 ± 0.35^{a}	5.91 ± 0.23^{b}	4.85 ± 0.25^{b}	125.01 ± 0.68^{a}
Oven-dried	23.11 ± 1.02^{a}	16.15 ± 0.93^{c}	3.89 ± 0.19^{a}	4.15 ± 0.71^{c}	6.45 ± 0.41^{a}	210.38 ± 0.89^{c}
Freeze-dried	23.98 ± 0.87^{a}	21.27 ± 0.82^{a}	2.21 ± 0.46^{b}	9.62 ± 0.40^{a}	1.20 ± 0.17^{c}	120.02 ± 0.78^{b}

Notes: Values are means ± SD of triplicate samples. Means with different superscript letter in a column are significantly different at $p \geq 0.05$

Table IV.
Effect of drying methods on color characteristics of beetroot slices

compared to other drying methods. Redness (a) of the powder was found to be best in freeze-dried samples to that of sun or oven-dried slices. Redness was found to decrease significantly ($p \geqslant 0.05$) during sun drying and was then further decreased significantly ($p \geqslant 0.05$) during oven drying. There was a significant ($p \geqslant 0.05$) increase in yellowness (b) when the slices were dried by sun or oven. However, this was found to increase with an increase in drying temperature (oven drying). This variation may be due to the fact that in Hunter Lab Colorimeter only surface color was measured. The results obtained for (L), (a) and (b) agree with those reported by Kowalski and Szadzinska (2014) who studied the effect of drying on beetroot. Quantification of pigments from extracts showed that for freeze-dried sample and fresh samples, betacyanin content was similar, which decreased with an increase in temperature. Also Betaxanthin content was similar in freeze-dried and fresh. Further increase in temperature resulted in increase in betaxanthin content. These results indicate that the red betacyanin is thermo-sensitive and destructs with increase in drying temperature forming yellow betaxanthin, which leads to increase in yellowness of beetroot powder. Increase in the yellow betaxanthin attributes toward the thermo-chemical transformation of betacyanin to betaxanthin or may be due to the increase in extractability of the betaxanthin with increase in drying temperature. It was observed that lightness (L) and redness (a) show same trend and that redness is directly proportional to lightness. Hence, when pigment content decreases, lightness increases and, hence, more redness is recorded on Hunter Lab. Beetroot contains very high amounts of red pigment and, hence, it appears dark when surface color was measured (low "L") and, hence, less redness is recorded. When freeze-dried samples were compared, redness was more in fresh sample although pigment content was same for both the samples. This may be due to the fact that freeze-drying retains very good texture, which in turn minimizes the sample shrinkage whereas in sun and oven-dried samples shrinks considerably. With the observation that increase in drying temperature decreases betacyanin (red pigment) and increases betaxanthin (yellow pigment), it was thought that at increased temperature, betacyanin was getting converted to betaxanthin.

Sun and oven drying were observed to decrease a/b ratio significantly ($p \geqslant 0.05$). However, freeze-drying had no effect on beetroot powder. The a/b ratio is commonly used as an index to report the color quality (brightness of the red color) of tomatoes (Arias *et al.*, 2000). Previous studies have reported a decrease in both L and a/b values after dehydration (Shi *et al.*, 1999). Toor and Georey observed a 21 percent decrease in a/b values when tomatoes were dehydrated at 42°C to a final dry matter content of 77 percent.

As shown in Table IV, the total color change (ΔE) of dried powder was varied depending on the drying method. The color assessment was realized through evaluation of the color difference between fresh and dried beetroot samples. An increased temperature of the drying agent causes a decomposition of betanin, so the decrease in lightness (L) and in redness (a) was observed for all of the samples after drying processes. The significantly ($p \leqslant 0.05$) higher difference in ΔE was observed in the sample dried by oven. However, only beetroot slices dried by freeze were characterized by a slight change in ΔE. Thus, the reduction in heating temperature significantly improved the color of beetroots after drying. The results obtained for ΔE agree with those reported by Kowalski and Szadzinska (2014) who studied the effect of drying on beetroot.

The browning index of fresh slices was observed to be varied between drying methods. Sun and oven drying of the slices significantly ($p \leqslant 0.05$) increased the browning index but freeze-drying had no significant effect. Acceptable color was observed in freeze-dried slices compared to that of sun-dried and oven-dried slices. The results indicated that freeze-drying retained the color of the slices. Moreover, the results obtained indicated that oven-dried slices developed brown color in beetroot slices. Similar results were reported by Babiker and Eltoum (2014) for tomato slices.

Conclusion

The results of this study showed that the chemical and minerals contents in slices were significantly higher by freeze-drying method than the conventional heat-drying methods. The bioactive compounds (betalains, total phenolics and flavonoids) and antioxidant activity were also higher in dried slices than fresh ones. The color of the slices was significantly affected by drying temperature. However, freeze-drying had no effect on color characteristics. The results indicated that freeze-drying retains the nutrients and color of the slices.

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