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ORIGINAL RESEARCH PAPER

Effect of Processing Methods on Bioactive Components and Antioxidant Activity of Beetroot (*Beta vulgaris* L.)

Sushan Niroula[1] and Babita Adhikari*[2]

[1]*Central Department of Food Technology, Tribhuvan University, Hattisar, Dharan-14, Nepal*

[2]*Department of Food Technology, Central Campus of Technology, Tribhuvan University, Hattisar, Dharan-14, Nepal*

Abstract

Beetroot (Beta vulgaris L.) is known as antioxidant, anti-inflammatory, hepato-protective and anticancer due to its bioactive components. The effect of processing (blanching, open pan cooking, pressure cooking, microwave oven treatment, electric oven treatment and drying) on the bioactive components (total phenolic and total betalain content) and antioxidant activity in beetroot were studied. The total betalain content (676.03 mg/100g db) included betacyanin (445.64 mg/100g db) and betaxanthin (230.39 mg/100g db). Total phenolic content, total betalain content and antioxidant activity were significantly different ($p<0.05$) in open pan cooked, pressure cooked and electric oven treated sample. The drying process significantly ($p<0.05$) decreased total phenolic and total betalain in blanched, open pan cooked, pressure cooked and electric oven treated samples. Betaxanthin was found more susceptible to heat than betacyanin. The antioxidant activity significantly ($p<0.05$) increased during drying of the pretreated samples. Microwave oven treatment was found to be suitable for pretreatment as it increases antioxidant activity, maximum retention in total phenolic content and betalain.

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*Corresponding author at:
Central Campus of Technology
Tribhuvan University
Hattisar, Dharan-14, Nepal.
E-mail address: babita.adhikari@cct.tu.edu.np

Introduction

Antioxidant constituent of the plant material act as radical scavengers, and helps in converting the radicals to less reactive species (Guine et al., 2015). The beetroot is good source of protein, carbohydrate, dietary fibre, minerals such as sodium and potassium and betalain, which makes it potential source for exploration and value addition in food beverages in combination with various fruit juices. It is the most potent vegetable in the world due to its various functional and medicinal properties. It is a rich source of bioactive compounds that include ascorbic acid, carotenoids, phenolic acids and flavonoids and other phytochemicals (Kujala et al., 2002). It contains a group of bioactive pigment known as betalain (Vulic et al., 2014). It is water soluble nitrogen containing plant pigment giving the red color of beetroot (Ravichandran et al., 2013), is immonium derivative of betalamic acid. They are divided in two structural groups, the yellow betaxanthin and red-purple betacyanin (Ninfali and Angelino, 2013). Betacyanin are a group of compounds exhibiting antioxidant and radical-scavenging activities (Pedreno and Escribano, 2000). They also inhibit cervical ovarian and bladder cancer cells in vitro (Zou

et al., 2005). Betalain and other phenolic compounds presented in beetroot decreases oxidative damage of lipids and improve antioxidant status in humans (Delgado-Vargas et al., 2000). It is an anti-inflammatory, hepato-protective and anticancer (Georgiev et al., 2010). It is one of the natural food which boosts the energy in athletes as it has one of the highest nitrates and sugar contents plant (Lee et al., 2005). Processing makes food healthier, safer, tastier and more shelf stable the functional properties of the plant can be retained maximum by suitable processing methods and the commercialization of processed product can be a way to provide a health beneficial product to the consumer. The cooking and drying processes would bring about a number of changes in physical characteristics and chemical composition of vegetables (Hamauzu and Zhang, 2004). Ismail et al. (2004) found that thermal treatment decreased the total phenolic content in all vegetables such as kale, spinach, cabbage, swamp cabbage and shallots and antioxidant activity in some of them. It indicated that processing caused little change to antioxidant potential of fruit and vegetables or enhanced it due to improvement of antioxidant properties of naturally occurring compounds or formation of novel compounds such as Maillard reaction products having antioxidant activity (Manzocco et al., 2001). The functional properties of the plant can be retained maximum by suitable processing methods and the commercialization of processed product can be a way to provide a health beneficial product to the consumer. The aim of the research was to establish the effect of various processing on the bioactive components and antioxidant activity of beetroot, in order to determine the most suitable method for higher retention of bioactive components and antioxidant activity.

Materials and Methods

Beetroot

The mature beet root (*Beta vulgaris* L.) cultivated in Dhankuta district, Nepal was sorted, cleaned, washed, peeled and sized to 1cm x 1cm x 1cm.

Pretreatments of beetroot

Blanching

The sample was blanched (500 g) in plain hot water at 80±2°C (sample: water ratio 1:3) for 1, 2, 3 and 4 min was quickly cooled and tested for blanching adequacy for optimization of blanching time as per Slavov et al. (2013). Briefly, to 10 ml of filtered in a test tube, 1 ml of 0.5% guaiacol and 1 ml 0.5% hydrogen-peroxide were added and allowed to stand for 4 minutes to observed the changes in color.

Open pan cooking

Fresh beetroot cubes (1 kg) were cooked in open pan (water and cubes ratio 1:1) at boiling water (100±2°C) for 5 min as described by Turkmen et al. (2005) with slight modification, which was then drained and cooled quickly to room temperature.

Pressure cooking

Fresh beetroot cubes (1 kg) were cooked (water to cubes ratio 1:1) in a pressure cooker at 120°C for 5 min as described by Slavov et al. (2013) with slight modification, was drained and cooled quickly to room temperature.

Microwave oven heating

Beetroot cubes were heated in microwave oven at 960 W for 3 min and were cooled quickly to room temperature as described by Slavov et al. (2013).

Electric oven heating

Beetroot cubes heated in electric oven at the temperature 100°C for 5 min as described by Turkmen et al. (2005) with slight modification, were cooled quickly to room temperature.

Drying of beetroot

Beetroot cubes (pretreated and fresh) were dried in cabinet drier at 50±5°C till to constant moisture content. The dried samples were packed in LDPE plastic bags (30-micron meter) and stored at 4°C (Bonazzi and Dumoulin, 2014).

Preparation of extract

The dried samples were extracted with 80% methanol for overnight, extract was collected and residue again was extracted for 1 h and

third extraction was carried for 30 min. The extract was filtered through Whatman filter paper 40 and stored at 4°C.

Determination of physical properties

The physical properties (length, diameter, color and shape) of fresh beetroot were observed. The mass was measured in weighing balance; length and diameter were measured by Vernier caliper. The largest length of oval beetroot was considered as maximum diameter.

Determination of proximate composition

The moisture content of the beetroot sample was determined by weight loss during heating (hot air oven at 105 ± 5°C); crude protein by micro Kjeldahl; fat by Soxhlet extraction using petroleum ether; total ash in muffle furnace (525°C for 5-6 h) and crude fibre as described in Ranganna (2007). Carbohydrate content was determined by difference method.

Total carbohydrate (%) = 100% – (moisture + crude protein + crude fat + crude fibre + total ash) %

Determination of iron

Iron content in the samples was determined by colorimetric method using Jenway Colorimeter (Model: 6051) at 480 nm as per Ranganna (1986). Briefly, 25 ml of 10% HCl was added to 1 g ash and volume (100 ml) was made. For spectrophotometric determination of iron content, blank, standard and sample solutions were made as per given in Table 1.

Table 1
Preparation of blank, standard and sample solution for iron determination

Constituent	*Blank (ml)*	*Standard (ml)*	*Sample (ml)*
Standard iron solution	0.0	1.0	0.0
Sample ash solution	0.0	0.0	5.0
Water	5.0	4.0	0.0
Conc. H_2SO_4	0.5	0.5	0.5
Potassium persulphate (Saturated)	1.0	1.0	1.0

The volume was made to 15 ml with water and observation was carried out setting the blank at 100% transmission.

Iron (mg/100 g) =

$$\frac{\text{OD of sample} \times 0.1 \times \text{Total volume of ash solution} \times 100}{\text{OD of standard} \times 5 \times \text{Wt. of sample taken for ashing}}$$

Determination of calcium

Calcium content of the sample was determined by titrimetric method (AOAC, 2005) with slight modification. Briefly, to 100 ml ash solution (1 g ash), 10 ml of saturated ammonium oxalate solution and 2 drop of methyl red indicator was added. Solution was made slightly alkaline by addition of dil. Ammonia and then slightly acid with few drops of acetic acid until color is faint pink (pH 5.0), heated to boiling point and cooled overnight at room temperature. Then, filtered the solution through Whatman No. 42 paper and washed with water, till the filtrate was oxalate free. The calcium was precipitated using hot dilute H_2SO_4 (1+4), precipitated was washed with hot water and titrated with hot 0.01 N $KMnO_4$ to the first permanent pink color. Finally, filter paper was added to the solution and complete titration was carried out.

Determination of potassium

The potassium content was determined by Microprocessor Flame Photometer (Model number: 1381) as described in Ranganna (1986) and the amount of radiation emitted is measured on spectrophotometer. Briefly, to a sample aliquot containing potassium less than 150 ppm, HCl was added to maintain same acid concentration as that of standard. The standard curve was plotted and the ppm of potassium was obtained from it.

Photometric quantification of betalain

Betalain are quantified as described by Kaokubaier et al. (2014) with slight modification. Betacyanin and betaxanthin contents of methanol extract were determined at 538nm and 480 nm respectively using AuCy visible spectrophotometer (Model Number: SSI-1104). The betalain content (BLC) will be calculated as Singleton & Rossi (1965).

$$\text{BLC (mg/L)} = \frac{A \times DF \times MG \times 1000}{e \times 1}$$

where A is the absorption value, DF the dilution factor, l is path length (1 cm) of the cuvette. For the quantification of betacyanin and betaxanthin the molecular weights (MW) and molar extinction coefficient (e) will be

respectively 550 g mol^{-1} and 60000 L mol^{-1} cm^{-1} in H_2O.

Determination of total phenolic content

Total phenolic content of the extract was determined by Folin-Coicalteu method as described in AOAC (2005) with slight modification. Briefly, dried sample (1g) was extracted with 10 ml 80% methanol and centrifuged at 3500 rpm at room temperature. Residue was re-extracted three times with 80% methanol and centrifuged. Then to, 2 ml methanolic extract, 1 ml distilled water, 0.5 ml Folin-Ciocalteu reagent were added and after 3 min 2 ml of 20% sodium carbonate was added. After allowing to react in dark for an hour, an absorbance was measured at 765 nm using AuCy visible spectrophotometer (Model Number: SSI-1104), Gallic acid solution (5-50 mg ml^{-1}) was taken as standard and the results will be expressed as mg of gallic acid equivalents (GAE) per 100 g dry basis of samples.

Antioxidant activity by radical scavenging activity

DPPH free radical scavenging activities of extracts was determined by methods described as Upadhyay et al. (2012) with slight variation. Briefly, sample (5g) was extracted in 80% methanol solution (100ml) for overnight. Then, 2 ml of 0.1 mM DPPH solution was mixed with 2 ml of extract and kept under dark condition for 30 minutes for complete reaction to take place. The anti-radial activity was determined at 517 nm using AuCy visible spectrophotometer (Model Number: SSI-1104). Control for the experiment was prepared by adding 2 ml of DPPH and 2 ml of methanol. The percentage DPPH radical scavenging activity will be calculated as following (Khalaf et al., 2009):

$$\textbf{DPPH Scavenging activity (\%)} = \frac{A_{control} - A_{sample}}{A_{control}} \times 100$$

Where $A_{control}$ and A_{sample} are absorbance of control and sample solution. The % DPPH scavenging activity versus concentration of sample (m/v) was plotted. The concentration of the sample necessary to decrease the DPPH concentration by 50% was obtained by interpolation from linear regression analysis and denoted as IC_{50} value (μg/ml).

Statistical analysis

The experiment was arranged as a Completely Randomized Design (CRD) with three replications. Each variation in the individual processing method was regarded as fixed factors. The data was analyzed by GenStat Release 12.1. Multiple comparison tests for observed means was done according to Tukey HSD, performed to identify differences between treatments at a significance level of $p < 0.05$.

Results and Discussion

Physical properties of beetroot

The data pertaining to various physical properties like mass, length, diameter, color and shape of whole beetroot were determined and the average values are presented in Table 2.

Table 2
Physical properties of beetroot bulb

Physical Parameter	*Values*
Mass (g)	127.27 ± 15.34
Length (cm)	10.20 ± 0.75
Diameter maximum (cm)	6.20 ± 0.56
Color (Visual)	Dark red
Shape	Oval

Note. Results are Mean ± SD of triplicate determinations

Analysis of fresh beetroot

Proximate composition of fresh beetroot

The analysis of the beetroot gives the information about the nutritional, mineral and biochemical composition. The moisture, crude protein, crude fat and crude fibre and minerals contents of the red beetroot were determined (Table 3). The protein content was similar to 10.714% as reported by Kale et al. (2018) but lower than 13.82% as reported by (Dambalkar et al., 2015; DFTQC, 2012). Dambalkar et al. (2015) reported that the fat content of beetroot is 1.45%. The result was lower than 2.38% as that claimed by Kale et al. (2018) as but higher than 0.81% as reported by (DFTQC, 2012) The total ash for beetroot was quite similar to value given by Kale et al. (2018) as 11.11%. The crude fibre content of the beetroot was higher than 7.31%. as that reported by DFTQC (2012) and Kale et al. (2018).

Mineral composition of fresh beetroot

Beetroot is well known for its mineral content and is rich in iron and potassium. The fresh beetroot was analyzed for its mineral content (Table 4). The iron content (16.66 mg/100 g db) is higher than 5.95 mg/100 g db as reported by Kale et al. (2018) and then 9.67 mg/100 g db as reported by DFTQC (2012). Straus et al. (2012) reported that iron content in beetroot grown at varying production system control, conventional, integrated and organic farming ranged from 18.9 to 25.2 mg/100 g db. The calcium content (153.22 mg/100 g db.) is within the range of 120-170 mg/100 g db as given by Straus et al. (2012) at different production system and higher than 146 mg/100 g db and 96.83 mg/100 g db as reported by DFTQC (2012) and Kale et al. (2018) respectively. The sodium content (587.08 mg/100 g db) is near to 576.03 mg/100 g db as given by Kale et al. (2018) and higher (611.11 mg/100 g db) than reported by Kumar (2015). The potassium content (3236.86 mg/100 g db) is higher (2903.66 mg/100 g db) than as reported by Kumar (2015).

Table 3
Proximate analysis of beetroot

Parameter	*Value*
Moisture (%)	89.49 ± 0.06
Protein (% db)	10.99 ± 0.09
Crude fat (% db)	1.32 ± 0.06
Total ash (% db)	11.08 ± 0.32
Crude fibre (% db)	9.80 ± 0.12
Carbohydrate (% db)	66.80 ± 0.73

Note. Results are Mean ± SD of triplicate determinations

Table 4
Mineral analysis of beetroot

Mineral	*Value*
Iron (mg/100 g db)	16.66 ± 0.45
Calcium (mg/100 g db)	153.22 ± 1.91
Sodium (mg/100 g db)	587.08 ± 0.58
Potassium (mg/100 g db)	3236.86 ± 9.52

Note. Results are Mean ± SD of triplicate determinations

Bioactive components and its antioxidant activity in fresh beetroot

The extract was analyzed for bioactive component and its antioxidant activity in spectrophotometer and the result are presented in Table 5.

Total phenolic content

Total phenolic activity (TPC) was 1966.46 mg GAE/100 g db which is near to 1983.39 mg GAE/100 g db as reported by Canadanovic-Brunet et al. (2011). Guldiken et al. (2016) reported that the total phenolic content of beetroot was 1863.65 mg GAE/100 g db and higher than 1339.49 mg GAE/100 g db as reported by Kugler et al. (2007) which may be due to the cultivar and season of production (Gorinstein et al., 1999).

Table 5
Analysis of bioactive components and its antioxidant activity

Parameter	Values
Total phenolic content (mg GAE/100 g db)	1966.46 ± 30.92
Antioxidant Activity (IC_{50} µg/ml)	459.44 ± 4.58
Betacyanin (mg/100 g db)	445.64 ± 4.27
Betaxanthin (mg/100 g db)	230.39 ± 6.26
Betalain (mg/100 g db)	676.03 ± 9.36

Note. Results are Mean ± SD of triplicate determinations

Total antioxidant activity

The DPPH scavenging abilities (IC_{50} value) of methanol extract (Figure 1) of fresh beetroot (459 µg/ml) is very close to Saani and Lawrence (2017) but higher than those reported by Stella (2011). The antioxidant capacity of beetroot juice was comparable to or higher than a variety of fruit and vegetable juices (Wootton-Beard and Ryan, 2011) and is greater than better known vegetable juices, such as tomato and carrot, and fruit juices such as orange and pineapple, with only pomegranate juice displaying a higher antioxidant capacity (Clifford et al., 2015).

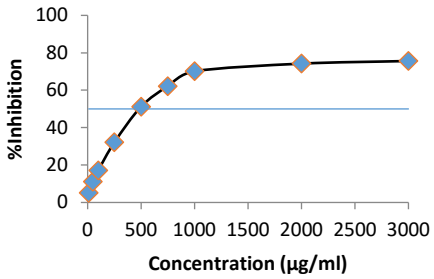

Figure 1
DPPH assay of fresh beetroot

Total betalain activity

The betalain content of fresh beetroot (676.03 mg/100 g db) is very near to those reported by Amirasgari and Mirsaeedghazi (2016) and lower than as reported by Bucur et al. (2016). The betacyanin and betaxanthin concentration was found to be 445.64 ± 10.23 mg/100 g db and 230.39 mg/100 g db respectively. The variation may be due to variety, cultivation area and climate of production.

Optimization of blanching time

Test for adequacy of blanching is shown in Table 6. The sample blanched for 3 minutes showed negative test result indicating that the optimum blanching time of 3 minute in 80 ± 2°C water was adequate for inactivation of peroxidase enzymes.

Table 5
Test for adequacy of blanching

Blanching time (minutes)	*Test result*
0	Positive
1	Positive
2	Positive
3	Negative
4	Negative

Effect of processing on bioactive components and antioxidant activity

Total phenolic content

There was no significant effect of blanching, microwave oven, electric oven treatment on total phenolic content (TPC) while the value lowered significantly ($p<0.05$) by 10.18% and 16.52% for pressure and open pan cooking respectively. Similarly, TPC was not significantly different among the blanched, electric oven and microwave oven heated sample; among blanched, open pan and microwave oven heated sample; between pressure and open cooked sample (Figure 2). According to Ismail et al. (2004) blanching for 1 min in boiling water reduced (4–26%) total phenolic content in beetroot. The loss in blanching, cooking might be due to leaching phenomenon in water (Ramos et al., 2017).

Total antioxidant activity

The microwave oven processing significantly ($p<0.05$) increased the IC_{50} value by 7.12% while electric oven processing significantly ($p<0.05$) decreased the value by 4.31% than blanched (6.14%), open pan cooked (9.46%) and pressure cooked (11.27%). ANOVA showed that there was no significantly difference ($p>0.05$) between open pan and pressure cooked; blanched and electric oven treated; blanched and open pan cooked sample (Figure 3). Saikia and Mahanta (2013) reported that the DPPH scavenging activity of beetroot was increased in microwave treated by 29% than in raw beetroot.

Total betalain content

The total betalain content (mg/100 g db) of blanching (542.66 ± 10.50), open pan cooked (538.36 ± 1.92), pressure cooked (519.86 ± 2.57), electric oven treated (491.77 ± 5.34) and microwave (603.17 ± 2.43) processing had significantly decreased ($p<0.05$) than the raw beetroot (676.03 ± 9.36) as shown in Figure 4. The loss of betacyanin was 4.74-24.77% while for betaxanthin ranges from 6.47% to 39.03%. The loss of betacyanin were reduced significantly ($p<0.05$) by 24.77%, 19.62%, 14.67%, 10.71% and 6.29% for electric oven, pressure cooking, blanching, cooking and microwave oven respectively. It was reported that betaxanthin is more heat sensitive than betacyanin as the loss percentage was higher in betaxanthin than betacyanin which is similar to Sapers and Hornstein (1979). The loss of betaxanthin was significantly reduced ($p<0.05$) during by 39.03%, 32.06%, 29.83%, 29.52% and 19.46% for open pan cooking, electric oven, pressure cooking, blanching and microwave oven. But, according to ANOVA there was no significant difference ($p>0.05$) in blanched, pressure cooked and electric oven

treated sample. Hence, the total loss of betalain contents was ranged from 10.78% to 27.26% for microwave oven treated and electric oven treated respectively. The loss of betalain content for pressure cooking, open pan cooking, blanching, and microwave oven heating are 23.10%, 20.36%, 19.73% and 10.78% respectively.

Betalain are lost at high temperatures, which explains the decrease in betalain concentration by all cooking methods (Ramos et al., 2017). Beets cooked in a pressure cooker had the highest loss (59.5%) compared to raw beet (Herbach et al., 2004). However, there was no statistically significant difference compared with oven-baked beets. Cooking methods that best preserved betalain content in beets were those immersed in water and steamed. According to Singh et al., (2015), there was a decrease of almost 10% in betalain concentration compared to that in raw beets. Ramos et al. (2017) reported that the betalain content decreased by 35% when immersed in boiling water. Even the minimal thermal treatment led to a decrease in the yield of the obtained betalain in the extracts (Ravichandran et al., 2013). It could also be seen that this was due to the higher decrease of the quantities of betaxanthin which are less stable during the thermal treatments (Herbach et al., 2004). Increasing the period of thermal red beet treatment led to an additional decrease of the betalain content in the extract (Georgiev et al., 2010).

Effect of drying on bioactive components and antioxidant activity in processed beetroot

Total phenolic content

The total polyphenolics content within the pretreatments were found to decrease significantly ($p<0.05$) after drying at 50°C (Figure 5). It was reported that TPC in each pre-treatment after drying decreased by 5.08%, 14.83%, 9.80%, 16.29% and 3.16% in microwave oven treated, electric oven treated blanched, pressure cooked and open pan cooked respectively. Davey et al. (2002) reported that loss of phenolic content was found to be lower with hot-air drying at 50°C is 33.75%. Felipe et al. (2010) reported that drying process led to loss of 30% of total phenol content in beetroot.

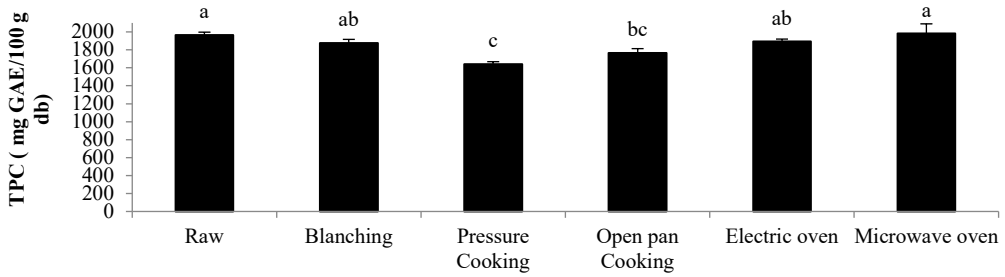

Figure 2
Effect of processing in total phenolic content

Note. Plotted values are means of 3 replicates. Vertical error bars represent standard deviations and values with different letters are significantly different ($p<0.05$) by Tukey HSD.

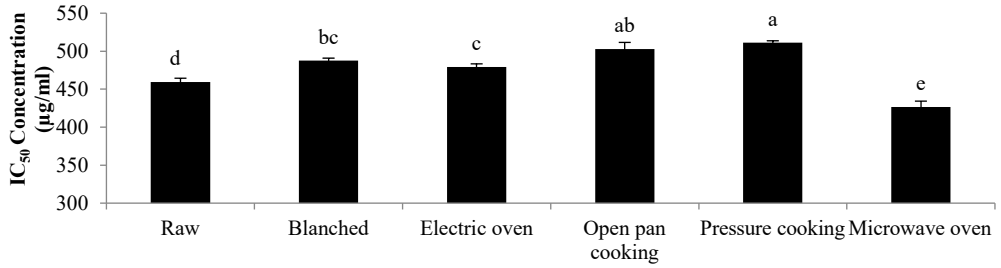

Figure 3
Effect of processing in antioxidant activity

Note. Plotted values are means of 3 replicates. Vertical error bars represent standard deviations and values with different letters are significantly different ($p<0.05$) by Tukey HSD.

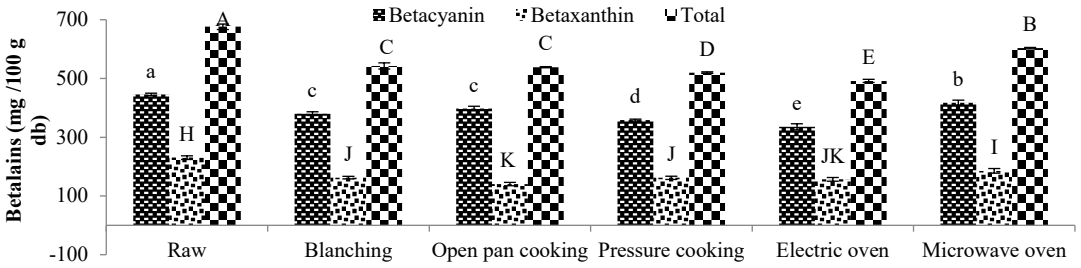

Figure 4
Effect of processing method in betalain content

Note. Plotted values are means of 3 replicates. Vertical error bars represent standard deviations and values with different letters are significantly different ($p<0.05$) by Tukey HSD.

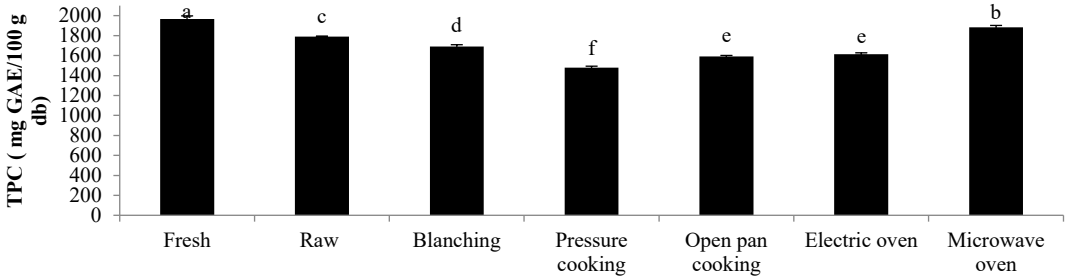

Figure 5
Effect of drying in total phenolic content

Note. Plotted values are means of 3 replicates. Vertical error bars represent standard deviations and values with different. letters are significantly different ($p<0.05$) by Tukey HSD.

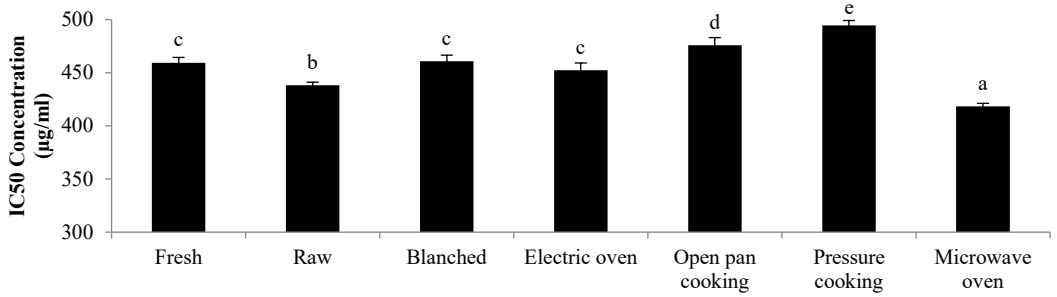

Figure 6
Effect of drying in antioxidant activity

Note. Plotted values are means of 3 replicates. Vertical error bars represent standard deviations and values with different letters are significantly different ($p<0.05$) by Tukey HSD.

Total antioxidant activity

The effect of drying on IC_{50} value (Figure 6) within microwave oven dried (418.45 ± 2.76 µg/ml), and raw dried (438.16 ± 2.99 µg/ml) had significantly reduced ($p<0.05$) by 8.92% and 4.63% respectively while drying had no significant effect ($p>0.05$) on IC_{50} within electric oven dried (452.37 ± 6.83 µg/ml) and blanched dried (460.76 ± 5.80 µg/ml). However, its value was increased significantly ($p<0.05$) by 3.57 and 7.67%. fresh (459.44 ± 4.98 µg/ml) open pan cooked (475.83 ± 7.23 µg/ml) and pressure cooked (494.70 ± 4.46 µg/ml). It was found that IC_{50} value was decreased (increase in antioxidant activity) after drying of pre-treatment as microwave oven treated (1.93%), pressure cooked (3.23%), blanched (5.38%), open pan cooked (5.38%) and electric oven treated (5.61%). Monreal et al. (2009) found no significant losses in the TAA (%) value when comparing beetroot chips and raw beetroots. Higher TAA (%) values for beetroot powder and beetroot chips were related to

drying of those formulations that removed water, thereby concentrating nutrients (Ravichandran et al., 2013).

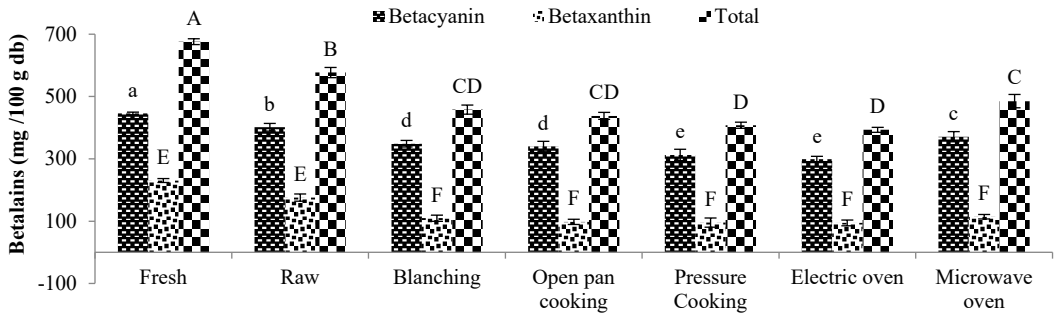

Figure 7
Effect of drying in betalain content

Note. Plotted values are means of 3 replicates. Vertical error bars represent standard deviations and values with different letters are significantly different ($p<0.05$) by Tukey HSD.

The high DPPH scavenging activity exerted by dehydrated samples can be due to the formation of compounds having powerful hydrogen donating ability (Zhang et al., 2009). Que et al. (2008) reported that hot air-dried pumpkin flour contained higher antioxidant activity possibly due to production of Maillard products. The increase in antioxidant capacity as a result of drying might be caused by the formation of new antioxidant compounds (Albanese et al., 2013).

Total betalain content

Drying significantly reduced ($p<0.05$) the total betalain content (TBC) with maximum destruction of betalain in electric oven treated sample (41.86%) followed by pressure-cooked sample (39.68%), open pan cooked sample (35.22%), blanched (32.26%), microwave oven treated (28.22%) and raw dried (14.66%) which is shown by Figure 7.

There was no significant effect of drying ($p>0.05$) on TBC within microwave treated, blanched and cooked dried. Similarly, there was no significant difference ($p>0.05$) on TBC between pressure cooked dried and electric oven dried. Similarly, it was found that the decrease in betalain content in respective pre-treated beetroot sample after drying were blanched (15.61%), open pan cooked (18.65%), microwave oven treated (19.54%), electric oven treated (20.00%), and pressure cooked (21.55%). It was found that betaxanthin (23.78-59.08%) is more susceptible to heat than betacyanin (9.96-32.95%) which is supported by Sapers and Hornstein (1979). There was no significant reduction ($p>0.05$) in raw dried betaxanthin than in fresh but it significantly reduced ($p<0.05$) in other processed dried samples. The betacyanin content in fresh was significantly higher ($p<0.05$) than in the processed dried beetroots. The maximum and minimum destruction of betacyanin were 32.96% and 9.95% and of betaxanthin were 59.08% and 23.78% in electric oven dried and raw dried sample respectively. During thermal treatment of betacyanin fractions their level decreased by 13% up to 15% depending on the cultivar. (Bator & Pawlak, 2016). Thermal treatment had a statistically significant effect in that it decreased yellow pigments content (Jimenez et al., 2004). The value obtained is similar to the result obtained by Ramos et al. (2017) which found significant decrease in betalain content after different dehydration methods. Temperature is the important factor influencing betalain stability (Ravichandran et al., 2013). Herbach et al. (2004) explained that thermal treatments decreased betalain stability.

Conclusion

Beetroot (*Beta vulgaris* L.) has good amount of protein, iron, potassium, sodium, calcium, total phenolic content and antioxidant activity but has low fat content. Optimum blanching time for beetroot was 3 min in 80 ± 2°C water. The total phenolic content was significantly ($p<0.05$) reduced in open pan and pressure cooking but insignificant ($p>0.05$) reduction in blanching, electric oven, and microwave oven processing. Retention of total phenolic in

pretreated dried cubes was significantly highest in microwave treated. Betalain was decreased significantly ($p<0.05$) during blanching, open pan cooking, pressure cooking, electric oven treatment, microwave treatment and drying process. Betaxanthin was found more susceptible to heat than betacyanin. Microwave treated sample has significantly ($p<0.05$) highest antioxidant activity and has least effect on total phenolic and betalain contents. Microwave treatment seems to be promising treatment for better retention for functional properties of beetroot.

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Compliance with Ethical Standards

Conflict of Interest

The authors declare no conflict of interest.

Ethical approval

The study did not involve any inhumane animal study.

References

Amirasgari, N., & Mirsaeedghazi, H. (2016). Non-thermal production of natural colorant concentrate form red beet extract by using the osmotic distillation. *Nutrition and Food Sci. Research*, *3*(2), 27-24. https://doi.org/10.18869/acadpub.nfsr.3.2.27

AOAC. (2005). *Association of Official Analytical Chemists* (18th ed.). CRC, Washington.

Bator, K. M. & Pawlak, S. (2016). The effect of thermal treatment on antioxidant capacity and pigment contents in separated betalain fraction. *Acta Sci. Pol. Technol. Aliment. 15*(3), 257-265. https://doi.org/10.17306/J.AFS.2016.3.25

Bonazzi, C., & Dumoulin, E. (2014). Quality changes in food materials as influenced by drying process. *Modern Drying Technology*, 1-20. https://doi.org/10.1002/9783527631728.ch14

Bucur, L., Taralunga, G., & Schroder, V. (2016). The betalains content and antioxidant capacity of red beet (*Beta vulgaris* L. ssp. *vulgaris*) root. *Farmacia*, *64*(2), 198-202.

Clifford, T., Howatson, G., West, D. J., & Stevenson, E. J. (2015). The potential benefits of red beetroot suplementation in health and disease. *Nutrients*, *7*, 2801-28022.

Canadanovic-Brunet, J. M., Savatovic, S., Cetkovic, G., Vulic, J. J., Markov, M. and Cvetkovic, D. (2011). Antioxidant and antimicrobial activity of beetroot pomace extracts. *J. Food Sci. 29*(6), 575-585.

Dambalkar, V. S., Rudrawar, B. D., & Poojari, V. R. (2015). Study of physico-chemical properties and sensory attributes of Beetroot-Oragne RTS drinks. *Int. J. of Sci. and Research*, *4*(10), 589-594.

Delgado-Vargas, F., Jimenez, A. R. and Paredes-Lopez, O. (2000). Natural pigments: carotenoids, anthocyanins, and betalains-characteristics, biosynthesis, processing, and stability. *Critical Reviews in Food Science and Nutrition*, *40*(3), 173-289.

DFTQC. (2012). Food Composition Table for Nepal. Department of Food Technology and Quality Control (Ministry of Agriculture Development), Nepal. pp. 1-80.

Felipe, C., Silva, C. S. d., Favaro-Trindade, S. M., Alencar, M. T. D. and Julio, C. B. (2010). Physicochemical properties, antioxidant activity and stability of spray-dried propolis. Kinetics, mineral content and colour characteristics of rosemary leaves. *Energy Convers*. *49*(2), 1258-1264.

Georgiev, V. G., Weber, J., Kneschke, E. M., Denev, P. N., Bley, T., & Pavlov, A. I. (2010). Antioxidant activity and phenolic content of betalain extracts from intact plants and hairy root cultures of the red beetroot Beta vulgaris cv. Detroit dark red. *Plant Foods Human Nutrition*, *65*(2), 105-111. https://doi.org/10.1007/s11130-010-0156-6

Gorinstein, S., Zemser, M., Haruenkit, R., Chuthakorn, R., Grauer, F., Martin-Belloso, O., & Trakhtenberg, S. (1999). Comparative content of total polyphenols dietary fibre in tropical fruits and persimmon. *J. of Nutritional Biochemistry*, *10*(5), 367-371.

Guine, R. P. F., Barroca, M. J., Gocalves, F. J., Alves, M., Oliveira, S., & Correia, P. M. R. (2015). Effect of Drying on Total Phenolic Compounds, Antioxidant Activity and Kinetics Decay in Pears. *Int. J. of Fruit Sci*., *15*(2), 173-186. https://doi.org/10.1080/15538362.2015.1017073

Guldiken, B., Toydemir, G., Memis, K. N., Okur, S., Boyacioglu, D., & Capanoglu, E. (2016). Home-processed red beetroot (*Beta vulgaris* L.) products: changes in antioxidant properties and bioaccessibility. *Int. J. of Mol. Sci.*, *17*(858). https://doi.org/10.3390/ijms17060858

Hamauzu, Y., & Zhang, D. (2004). Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. *Food Chem. 88*(4), 503-509.

Herbach, K. M., Stintzing, F. C., & Carle, R. (2004). Impact of thermal treatment on colour and pigment pattern of red beet (*Beta vulgaris* L.) preparations. *J. of Food Sci*., *69*, 491–498. https://doi.org/10.1111/j.1365-2621.2004.tb.10994.x

Ismail, A., Marjan, Z. M., & Foong, C. W. (2004). Total antioxidant activity and phenolic content in selected vegetables. *Food Chem*., *87*, 581-586. https://doi.org/10.1016/j.foodchem.2004.01.010

Jimenez, S., Benitez, R., Prota, H. and Sosa, R. (2004). Betacyanin synthesis in red beet (Beta vulgaris L.) leaves induced by wounding and bacterial infiltration is preceded by an oxidative burst. *Physiol. Mol. Plant*, 64 (4), 125-133.

Kale, R. G., Sawate, A. R., Kshirsagar, R. B., Patil, B. M., & Mane, R. P. (2018). Studies on evaluation of physical and chemical composition of beetroot (*Beta vulgaris* L.). *Int. J. of Chemical Studies*, *6*(2), 2977-2979.

Kaokubaier, H. B. H., Snoussi, A., Essaidi, I., Chaabouni, M. M., Thonart, P., & Bouzouita, N. (2014). Betalain and phenolic compositions, antioxidant activity of Tunisian red beet (*Beta vulgaris* L.) roots and stems extracts. *Int. J. of Food Properties*, *17*(9), 1934-1945. https://doi.org/10.1080/10942912.2013.772196

Kugler, F., Stintzing, F. C., & Carle, R. (2007). Evaluation of the antioxidant capacity of betalainic frutis and vegetables. *J. of Applied Botany and Food Quality*, *81*, 69-76.

Kujala, T. S., Vienola, M. S., Klika, K. D., Loponen, J. M., & Pihlaja, K. (2002). Betalain and phenolic compositions of four beetroot (*Beta vulgaris* L.) cultivars. *Europe Food Research Technol*., *214*(6), 505-510.

Kumaar, S. (2014). The importance of antioxidant and their role in pharmaceutical science. *Asain J. of Research in Chem. and Pharmaceutical Sci.* **1** (1), 27-44.

Lee, C. H., Wettasinghe, M., Bolling, B. W., Ji, L. L., & Parkin, K. (2005). Betalains, phase II enzyme-inducing components from red beetroot (*Beta vulgaris L.*) extracts. *J. of Agri. and Food Chem. 50*(23), 6704-6709.

Manzocco, L., Calligaris, S., Mastrocola, D., Nicoli, M. C., & Lerici, C. R. (2001). Review of non-enzymatic browning and antioxidant capacity in processed foods. *Trends in Food Sci. and Technol*., *11*(9), 340-346. https://doi.org/10.1016/S0924-2244(01)00014-0

Ninfali, P., & Angelino, D. (2013). Nutritional and functional potential of *Beta vulgaris cicla* and *rubra*. *Fitoterapia*, *89*(6), 188-199.

Pedreno, M. A., & Escribano, J. (2000). Studying the oxidation and the antiradical activity of betalain from beetroot. *J. Biological Education*, *35*(1), 49-51.

Ramos, J. A., Furlaneto, K. A., Mendonca, V. Z. d., Carvalho, F. A. d., Lundgren, G. A., Fujita, E., & Vieites, R. L. (2017). Influence of cooking methods on bioactive compounds in beetrot. *Semina: Ciencias Agrarias*, *38*(3), 1295-1302. https://doi.org/10.5433/1679-0359.2017v38n3p1295

Ranganna, S. (1986). Handbook of analysis and quality control for fruit and vegetable products (2nd ed.), Tata Moisture content Graw-Hill Publishing Co. Ltd, New Delhi.

Ravichandran, K., Saw, N. M. M. T., Mohdaly, A. A. A., Gabr, A. M. M., Kastell, A., Riedel, H., Cai, Z., Knorr, D., & Smetanska, I. (2013). Impact of processing of red beet on betalain content and antioxidant activity. *Food Research Intl*., *50*, 670-675. https://doi.org/10.1016/j.foodres.2011.07.002

Saikia, S. and Mahanta, C. L. (2013). Effect of steaming, boiling and microwave cooking on the total phenolics, flavonoids and antioxidant properties of different vegetables of Assam, India. *Int. J. of Food and Nutritional Sci*. 2 (3), 47-53.

Sapers, G. M. and Hornstein, J. S. (1979). Varietal differences in colorant properties and stability of red beet pigments. J. of Food Sci. 44, 1245-1248.

Singh, S., Swain, S., Singh, D. R., Salim, K. M., Nayak, D., & Roy, S. D. (2015). Changes in phytochemicals, anti-nutrients and antioxidant activity in leafy vegetables by microwave boiling with normal and 5% NaCl solution. *Food Chem*., *176*(2), 244-253. https://doi.org/10.1016/j.foodchem.2014.12.068

Singleton, V., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphmolybdic phosphotungstic acid "reagents". *Am. J. Enol. Vitic*., *16*, 144-158.

Slavov, A., Karagyozov, V., Denev, P., Kratchanova, M., & Kratchanov, C. (2013). Antioxidant activity of red beet juice obtained after microwave and thermal pretreatments. *Czech. J. Food Sci*., *31*(2), 139-147.

Straus, S., Bavec, F., Turinek, M., Slatnar, A., Rozman, C., & Bavec, M. (2012). Nutritional value and economical feasibility of red beetroot (*Beta vulgaris* L. ssp. *vulgaris* Rote Kugel) from different production systems. *African J. of Agri. Research*, *7*(42), 5653-5660. https://doi.org/10.5897/AJAR12.1519

Turkmen, N., Sari, F., & Velioglu, Y. S. (2005). The effect of cooking methods on total phenolics and antioxidant activity of selected green vegetables. *Food Chem*., *93*, 713-718. https://doi.org/10.1016/j.foodchem.2004.12.038

Upadhyay, A., Chompoo, J., Araki, N. and Tawata, S. (2012). Antioxidant, antimicrobial, 15-LOX, and AGEs inhibitions by Pineapple Stem Waste. *J. of Food Sci*. *71*(7), H9-H15.

Vulic, J. J., Cebovic, T. N., Canadanovic-Brunet, J. M., Cetkovic, G. S., Canadanovic, V. M., Djilas, S. M., & Saponjac, V. T. T. (2014). In vivo and in vitro antioxidant effects of beetroot pomace extracts. *J. Functional Foods*, *6*, 168-175. https://10.1016/j.jff.2013.10.003

Zhang, Z., Guoying, L., Pan, H., Wu, Y. and Fan, L. (2009). Effects of different drying methods andextraction condition on antioxidant properties of shiitake (*Lentinus edodes*). *Food Sci. Technol. Research*, *15*(5), 547-552.

Zou, D. M., Brewer, M., Gracia, F., Feugang, J. M., Wang, J., Zang, R., Liu, H., & Zou, C. (2005). Cactus pear: a natural product in cancer chemoprevention. *Nutrition J.*, *8*(4), 25.