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Determination of Nutrient Values of Tuberous Vegetables Using Different Cooking Methods

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Abstract

Objective: To investigate the nutrient quality of tuberous vegetables using different cooking methods such as boiling, steaming, and microwaving. Carrot (*Daucus carota*), radish (*Raphanus sativus*), and beetroot (*Beta vulgaris*) were used for the study. **Results:** This study identified the best cooking method for retaining nutrients and antioxidant activity in carrot, beetroot, and radish samples. Physiochemical analysis (pH and color measurement), nutrient quality testing (ascorbic acid, beta-carotene, total flavonoid content, total phenolic content, and iron), and antioxidant activity were done. It was observed that steaming is the best cooking method for retaining nutrients and antioxidant activity in carrot, beetroot, and radish samples. It minimizes nutrient loss and preserves antioxidant activity, making it a recommended cooking method compared to the other methods.

Keywords: Antioxidant activity, *Beta vulgaris*, *Daucus carota*, Nutrient quality, *Raphanus sativus*

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Introduction

Tuber vegetables are an essential part of a healthy diet. They provide vital nutrients fiber and antioxidants. Carrot (*Daucus carota*), radish (*Raphanus sativus*), and beetroot (*Beta vulgaris*) are three commonly consumed tuber vegetables providing unique nutritional benefits each offering unique properties. This analysis provides the nutrients quality of these vegetables and explores the effects of four different cooking methods: Raw, boiling steaming and microwaving.[1]

Essential elements, such as vitamins, minerals, antioxidants, and dietary fiber, are abundant in vegetables such as radish, carrot, and beetroot. However, differing cooking techniques can have a substantial impact on their nutritional makeup. Depending on the technique, cooking changes the bioavailability of nutrients, increasing or decreasing their concentrations.[2,3]

The purpose of this study is to assess how different cooking methods such as boiling, steaming, and microwaving affect the nutritional value of beetroot, carrot, and radish. Key nutritional components are influenced differently by each technique. For example, steaming may help retain more nutrients, whereas boiling may cause water-soluble vitamins, such as vitamin C, to leak. Furthermore, some cooking techniques may increase the bioavailability of antioxidants in beetroot or beta-carotene in carrots.[4,5]

This study attempts to identify the best cooking techniques that maintain or improve the nutritional content of these vegetables by comparing their nutrient quality before and after cooking. The results offered important information about the best cooking methods to optimize their health advantages.

Materials and Methods

Collection and Preparation of Samples

The tuber vegetable samples carrot, radish, and beetroot were collected from the local market, washed, dried, and diced into 1 cm pieces each and used for the study.

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Cooking Methods

100 g of each sample washed, dried, and diced into small portions of equal size was used as samples.

- Boiling: Sample submerged in 250 mL of water at 100°C for 5 min
- Steaming: Sample was steamed at 100°C for 5 min in a closed vessel
- Microwaving, sample heated with 25 mL of water at 600–800 watts for 2 min.

Physiochemical Analysis

pH measurement

To measure the pH of raw, boiled, steamed, and microwaved carrot, beetroot, and radish samples.

Procedure

Calibrate the pH meter using pH 4, 7, and 9 buffer solutions. Prepare four sets of samples for each vegetable: Raw, boiled, steamed, and microwaved. Measured the pH of each sample using the pH meter. Recorded the pH values for each sample.[6]

Color measurement

To measure the color of boiled, steamed, and microwaved carrot, beetroot, and radish samples at three different wavelengths (540, 580, and 649 nm).

Procedure

Prepared three sets of samples for each vegetable: Boiled, steamed, and microwaved. Measured the color of each sample using the colorimeter at three different wavelengths (545, 580, and 649 nm). Recorded the color values for each sample. Calculate the color difference and color retention for each sample.

Nutrient Quality Testing

Ascorbic acid (Vitamin C)

Procedure

The ascorbic acid content in carrot, beetroot, and radish samples is determined by first weighing 1 g of each vegetable sample. Then, 10 mL of 0.56 M sodium oxalate solution is added to the sample. The sample and sodium oxalate solution are mixed for 2 min and then allowed to settle for 5 min. After settling, 0.5 mL of the supernatant is taken and diluted to 5 mL with distilled water. The absorbance of the sample is then measured using a spectrophotometer at 266 nm, with 0.056 M sodium oxalate solution used as the blank. Finally, the ascorbic acid content is calculated and expressed as 1 mg/10 mL of sample.[7]

β – Carotene

Procedure

The beta carotene content in carrot, beetroot, and radish samples is determined by first weighing 1 g of each vegetable sample. Then, 10 mL of distilled water is added to the sample and mixed for 2 min. Next, 5 mL of hexane is added to the mixture, which is then stirred for 1 min and left to settle for 5 min. After settling, the mixture is stirred again for 1 min and the supernatant is carefully collected. The absorbance of the supernatant is then measured using a spectrophotometer at 452 nm. The beta carotene content is calculated using formula.

Extract Preparation

To prepare extracts from raw, boiled, steamed, and microwaved carrot, beetroot, and radish samples for analysis of total phenolic content (TPC), flavonoid content, 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity, and 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) radical scavenging activity.

Procedure

The extract preparation involves weighing 10 g of each vegetable sample, adding 40 mL of 60% methanol solution, and mixing for 2 min. The mixture is then incubated with shaking incubator at 100 rpm for 45 min, followed by centrifugation at 4000 rpm for 10 min. The resulting mixture is filtered through paper to obtain the extract, which is stored in a dark container at 4°C. This extract will be used for the analysis of TPC, flavonoid content, DPPH radical scavenging activity, and ABTS radical scavenging activity.

Total flavonoid content (TFC)

To determine the TFC in raw, boiled, steamed, and microwaved carrot, beetroot, and radish extracts.

Procedure

The TFC is determined by preparing a reaction mixture consisting of 1.5 mL of 95% ethanol, 0.1 mL of 10% aluminum chloride, 0.1 mL of 1M potassium acetate, and 2.8 ml of distilled water. The diluted sample is made by 1 mL of 95% ethanol into 200 μL of the vegetable extract. 1 mL of the diluted sample is mixed with 4.5 mL of the reaction mixture and vortexed for 5 min. The mixture is then incubated at 25°C for 40 min, and the absorbance is measured at 415 nm using a ultraviolet (UV)-visible spectrophotometer. The TFC is calculated using a quercetin standard curve and expressed as mg quercetin equivalent per 10 mL.

TPC

Procedure

The TPC is determined by preparing a reaction mixture consisting of 2.5 mL of 0.2N FC reagent and 2.5 mL of 7.5% sodium carbonate solution. 1 mL of the diluted sample extract is then added to 4.5 mL of the reaction mixture. The mixture is incubated at room temperature for 30 min, and the absorbance is measured at 765 nm using a UV-visible spectrophotometer. The TPC is calculated using the formula.[8]

Iron

Procedure

The sample is ashed in a muffle furnace. Then, 10 mL of 2M HCl solution is added to the ashed sample. The mixture is stirred for 1 min, and 10 mL of distilled water is added to it. The mixture is then filtered using Whatman filter paper. The absorbance of the filtrate is recorded at 458 nm using a spectrophotometer.

Radical Scavenging Activity

DPPH radical scavenging activity

Procedure

0.0394 g of DPPH is dissolved in 100 mL of 100% methanol in a 100 mL flask. 1 mL of this DPPH solution is mixed with 1 mL of sample extract. The mixture is incubated in the dark for 30 min. The absorbance is measured using a spectrophotometer at 517 nm.

ABTS radical scavenging activity

Procedure

0.1914 g of ABTS is mixed with 100 mL of PBS. 10 mL of this ABTS solution is then mixed with 10 μL of 140 mM potassium persulfate solution. The mixture is then incubated for 16 h in the dark to form ABTS radicals. 1 mL of the ABTS radical solution is then mixed with 1 mL of sample extract. The mixture is incubated in the dark for 6 min. The absorbance is measured at 734 nm using a spectrophotometer.[9]

Results and Discussion

Physiochemical Analysis

This analysis involves measuring the pH and color properties of raw, boiled, steamed, and microwaved carrot, beetroot, and radish samples to assess the effects of different cooking methods [Figure 1]. pH is measured using a pH meter, while color is analyzed at wavelengths of 540, 580, and 649 nm.

pH

From Table 1, it is observed that the pH of raw samples was higher than cooked ones, with boiling and microwaving causing a greater decrease while steaming preserved the pH. Similarly, in Assam vegetables (such as Water Spinach, and Yam), cooking reduced pH and color, primarily due to the loss of water-soluble compounds and heat-induced degradation of pigments such as carotenoids and anthocyanins.[10,11]

Color measurement

It was observed that tuber vegetables when cooked in different methods caused the reduction of color in each method using three different wavelengths as depicted in Table 2.

In a study, the pigments responsible for the color reduction in these vegetables include β – carotene, anthocyanins, carotenoids, betalains, and other water-soluble pigments which are responsible for the color in tuber vegetables. The researchers investigated the effects of different cooking methods on kale and found that cooking caused a significant color reduction due to chlorophyll degradation, cellular structure disruption, and loss of water-soluble pigments. The mechanism of color reduction includes the heat degradation, water solubilization, and enzymatic degradation of the pigments while cooking reduces the color of the vegetable. Hence, the absorbance of the samples at each cooking method is reduced.[7]

Table 1: pH values of tubers using different cooking methods

Samples	*Methods of cooking*			
	Raw (control)	*Boil*	*Steam*	*Microwave*
Carrot	7.60±0.49	6.51±0.511	6.80±0.41	6.52±0.21
Radish	7.30±0.33	6.20±0.24	6.52±0.35	6.33±0.35
Beetroot	7.30±0.98	6.25±0.28	6.84±0.48	6.57±0.47

Nutrient Quality Testing

Nutrient quality testing is to assess the impact of different methods of cooking on the retention of essential nutrients including ascorbic acid, β-carotene, flavonoids, phenolic compounds, and iron in vegetables. It helps to compare the effect of steaming, boiling, and microwaving on nutrient concentration and antioxidant properties of vegetables as shown in Table 3.

Ascorbic acid (vitamin C)

The cooking methods break down the ascorbic acid molecules, causing the loss of vitamin C, reducing the ascorbic acid value during each of the cooking processes. In the present study, the steaming process has retained more Vitamin C than the boiling and microwave. According to the study done with leafy green vegetables, using excess water and heat causes more loss of ascorbic acid as it is sensitive to them. Hence, boiling and microwaving lose more, but steaming retains the Vitamin C more than the boiling and microwaving.[2,16]

β – carotene

Compared to boiling and microwaving, steaming retains more beta-carotene in carrots, radish, and beetroot, because steaming

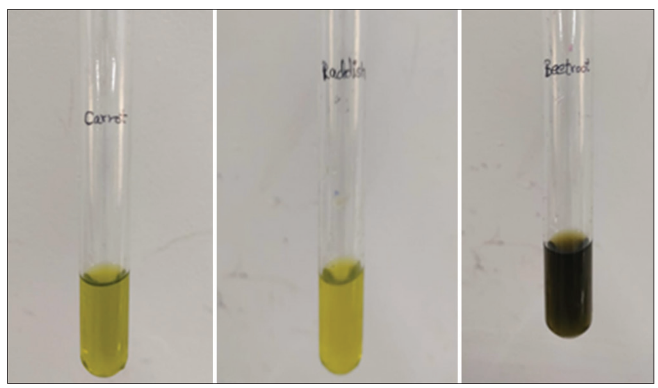

Figure 1: Extract of the tuberous vegetables (Carrot, Radish, Beetroot)

Table 2: Color difference (ΔE) and color retention (%) of tuberous vegetables using different cooking methods

Samples	*Boil*	*Steam*	*Microwave*
Carrot	ΔE=0.31	ΔE=0.14	ΔE=0.23
	CR%	CR%	CR%
	540 nm-86.31±0.21	540 nm-93.54±0.28	540 nm-89.92±0.33
	580nm- 8.80±0.35	580 nm-95.41±0.39	580 nm-92.10±0.42
	640 nm-85.73±0.42	640 nm-95.26±0.26	640 nm-90.54±0.36
Radish	ΔE=0.14	ΔE=0.06	ΔE=0.11
	CR%	CR%	CR%
	540 nm-81.61±0.42	540 nm-91.83±0.27	540 nm-85.71±0.27
	580 nm-78.10±0.31	580 nm-93.80±0.42	580 nm-84.41±0.30
	640 nm-84.85±0.26	640 nm-96.91±0.38	640 nm-90.91±0.36
Beetroot	ΔE=0.22	ΔE=0.08	ΔE=0.15
	CR%	CR%	CR%
	540 nm-92.10±0.41	540 nm-97.46±0.24	540 nm-95.42±0.20
	580 nm-88.51±0.38	580 nm-96.28±0.23	580 nm-92.33±0.39
	640 nm-89.92±0.25	640 nm-97.10±0.37	640 nm-93.52±0.28

Figure 2: Vegetable samples (Carrot, Radish, Beetroot) to ash in the muffle furnace

Table 3: Result values of nutrient quality testing assays of raw and cooked vegetables

Sample (10 g)	*Method*	*Vitamin C (1 mg/10 mL) 265 nm*	*Beta Carotene (mg/10 mL) 452 nm*	*Flavonoid (mg/10 mL) 415 nm*	*Phenolic Content (mg GAE/10 mL) 765 nm*	*Iron (mg/10 mL) 485 nm*
Carrot	Raw (standard)	3.00±0.51	6.00±0.11	161.11±2.5	109.33±1.93	8.00±0.51
	Boil	2.50±0.25	4.50±0.46	133.51±1.8	88.13±1.62	4.60±0.27
	Steam	2.80±0.33	5.50±0.49	150.27±2.3	96.00±1.86	6.20±0.42
	Microwave	2.60±0.29	5.00±0.32	140.22±1.3	84.27±1.37	3.00±0.35
Radish	Raw (standard)	3.00±0.32	3.57±0.27	40.93±1.90	80.00±1.61	130.00±2.01
	Boil	2.40±0.50	2.50±0.38	29.93±1.27	66.80±1.33	114.00±1.66
	Steam	2.70±0.26	3.20±0.23	35.44±1.61	73.33±1.52	122.00±1.97
	Microwave	2.50±0.38	2.80±0.37	32.44±1.32	62.00±1.27	108.00±1.94
Beetroot	Raw (standard)	3.00±0.41	6.21±0.52	51.93±2.06	371.33±2.42	7.60±0.67
	Boil	2.20±0.52	4.50±0.39	43.49±1.46	303.07±1.86	4.20±0.48
	Steam	2.60±0.46	5.70±0.43	48.49±1.82	320.00±2.08	5.80±0.53
	Microwave	2.40±0.38	5.00±0.47	45.49±1.37	296.80±1.90	2.60±0.40

uses minimal water and heat so the degradation of beta-carotene is less. According to the study[13] by Sharma *et al*., (2016) with carrot, beta-carotene is a fat-soluble vitamin and it is sensitive to heat, oxygen, and light. Cooking methods can break down beta-carotene molecules and cause loss of Vitamin A [Figure 2].

TFC

In the current study, it was observed that steaming does not lose more flavonoids as less heat and water are used, compared to other cooking methods. The study states that flavonoids are sensitive to heat, water, and oxygen which causes degradation during cooking. The reduction in the TFC causes hydrolysis and breaks down the glycosidic bonds between them and also causes certain enzyme degradation. These result in the loss of antioxidant activity as proved by Hosseinian *et al*., (2007).[14]

TPC

The results showed that steaming minimizes the degradation and retains more phenolic content than boiling and microwaving. According to research conducted by Mishra *et al*., (2011) phenolic compounds are sensitive to heat, water, and oxygen, degrading during cooking through hydrolysis, oxidation, and enzyme degradation. This results in loss of antioxidant activity.[15]

Iron

In the present study, it was noted that the iron content of carrots, radish, and beetroot decreased after cooking. Boiling and microwaving showed maximum loss. Desai *et al*., (2018) conducted a similar study and stated that the decrease in iron content is due to its leaching into the cooking water, particularly during boiling. However, steaming retained more iron than boiling and microwaving, due to less water and heat.

Radical scavenging activity

The DPPH and ABTS free radical scavenging assay helps to determine the antioxidant levels in the tuberous vegetables using different cooking methods such as boiling, steaming, and microwaving. The results are shown in Table 4.

DPPH radical scavenging activity

The result showed better DPPH radical scavenging activity % in the microwaved sample than the other two cooking methods. The study states that the decrease in DPPH radical scavenging activity after cooking causes the degradation of polyphenolic compounds, including flavonoids and phenolic acids. These compounds are sensitive to heat, water, and oxygen, which can cause them to break down and lose their antioxidant activity. This is the reason for decrease in the percentage of the DPPH radical scavenging activity %.[5,17]

ABTS radical scavenging activity

The ABTS radical scavenging activity of carrots, radish, and beetroot increased after cooking, with microwaving showing the highest free radical scavenging activity compared to the rest. By the study performed, it is understood that this increase is by the breakdown of cell walls, releasing more antioxidants. The heat from cooking can enhance the extraction of antioxidants and create higher ABTS radical scavenging activity %.

In a study, researchers measured the ABTS radical scavenging activity in various vegetable extracts. They found

Table 4: Free radical scavenging activities of tuberous vegetables using different cooking methods

Sample (1 mg/10 mL)	*Methods of cooking*	*DPPH (%)*	*ABTS (%)*
		Percentage of scavenging activity	
Carrot	Raw (control)	89.50±1.22	68.00±1.03
	Boil	82.30±1.07	46.90±1.21
	Steam	82.00±0.83	44.40±1.17
	Microwave	84.10±1.15	51.60±1.01
Radish	Raw (Control)	85.40±1.57	69.80±1.63
	Boil	76.80±1.08	56.80±1.48
	Steam	76.20±1.31	54.20±1.14
	Microwave	77.70±1.45	59.80±1.49
Beetroot	Raw (Control)	68.75±1.48	53.80±1.43
	Boil	55.00±0.91	54.80±1.07
	Steam	52.00±1.06	49.80±1.01
	Microwave	56.25±1.27	49.80±1.22

DPPH: 2,2-diphenyl-1-picrylhydrazyl, ABTS: 2,2′-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid

that cooking, particularly using methods that break down cell walls (like steaming or microwaving), increased the ABTS radical scavenging activity. This was attributed to the enhanced extraction of antioxidants during cooking, as heat and the breakdown of cellular structures release more bioactive compounds, including phenolic, that are responsible for scavenging free radical.[5]

Conclusion

The result showed a significant effect of cooking methods on both nutrient content and antioxidant activities of the above vegetables. Steam cooking followed by microwaving and boiling showed the best results that could restore the nutrient values. Boiling was found to cause significant loss in the water-soluble vitamins, minerals, and antioxidants. Antioxidant activity of these vegetables also differed due to cooking in measurements by DPPH and ABTS radical scavenging assays. Steaming and microwaving were found to generate more antioxidant activity than boiling. Hence, steaming is the best cooking method for nutrient retention and antioxidant activity for carrot, beetroot, and radish samples. To optimize a household's nutrient retention, it could include steaming as the primary cooking method, minimizing amounts of water, time of cooking and preventing trappings and preserve these tuber vegetables nutritional qualities.

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