Hindawi
Journal of Food Quality
Volume 2020, Article ID 8908670, 5 pages
https://doi.org/10.1155/2020/8908670

Research Article

Effect of Cooking Methods on Ascorbic Acid Destruction of Green Leafy Vegetables

Gebrehana Ashine Hailemariam[1] **and Tadele Andargie Wudineh**[2]

[1]*Food Engineering, Technology Institute, Debre Berhan University, P.O. Box 445, Debre Berhan, Ethiopia*
[2]*Food Engineering, Faculty of Chemical & Food Engineering, Bahir Dar University, P.O. Box 26, Debre Berhan, Ethiopia*

Correspondence should be addressed to Gebrehana Ashine Hailemariam; gebrehana2000@gmail.com

Received 3 September 2019; Revised 29 January 2020; Accepted 5 February 2020; Published 9 March 2020

Guest Editor: Juan Luis Valenzuela

Ascorbic acid is highly sensitive vitamin to various modes of cooking processes. Ethiopian green collards (*Brassica carinata*), locally called *Ye'abesha Gomen*, and cabbage (*Brassica oleracea*) are important green vegetables for ascorbic acid source in the country. The rate of ascorbic acid degradation in cabbage and Ethiopian green collard was studied employing two processing methods: open-pan and pressure cooking which are highly customized in household cooking. Samples were cooked at 5, 10, 15, 20, 25, 30, and 35 min under each processing method. Ascorbic acid concentration in each sample was determined by using a spectrophotometer at 520 nm wavelength using the standard plot of pure ascorbic acid solution. The initial concentration of ascorbic acid in fresh cabbage and Ethiopian green collard were found to be 33.76 ± 0.58 and 38.14 ± 0.19 mg/100 g, respectively. Well-cooked and edible Ethiopian green collard was obtained at 10 minutes of cooking time by pressure cooking with ascorbic acid retention of 31.8% from its initial contents. However, a cooking time of 25 min was required by the open-pan cooking method with 26.8% ascorbic acid retention. Edible cabbage was attained at 10 and 20 minutes of cooking time by pressure and open-pan cooking methods maintaining 36.9 and 30.9% of ascorbic acid, respectively. Thus, the pressure cooking method required short cooking time for having well-cooked and edible green leafy vegetable with better ascorbic acid retention. The outputs of this work would be helpful to design and control practical thermal processing situations and to minimize the loss of ascorbic acid in green leafy vegetables.

1. Introduction

Vegetables and fruits are rich sources of essential vitamins, minerals, fibers, and disease-fighting phytochemicals which the human body needs to maintain good health. Although consumption of fresh unprocessed plant food is widely advocated, evidence is emerging that bioavailability of many protective compounds is enhanced when vegetables are cooked [1]. The type of processing affects the extent to which a vegetable food is a good source of a nutrient [2]. The processing needs to be designed and controlled to give the product qualities identified and wanted by the consumers [3].

Recent studies shown that selection of proper cooking methods can enhance the availability of healthy nutrients. Steaming, roasting, boiling, frying, sautéing, and microwave and pressure cooking are found to be the most common methods for cooking vegetables [4]. Moreover, the researchers also considered in their work, factors related to the preparation phase of common domestic processing, including washing, peeling, cutting, chopping, and soaking [5]. Such information has been studied in detail for broccoli [1, 6–14]. However, data on the effect of cooking on nutritional properties of cabbage and Ethiopian green collard are still incomplete. Understanding how and why nutrient losses are therefore helpful for the consumer, chef, and food processor to limit such losses and enhance the nutritional quality of leafy vegetables.

Ethiopian green collard (*Brassica carinata*), locally named *Ye'abesha Gomen*, and cabbage (*Brassica oleracea*)

are important green leafy vegetables for ascorbic acid source in Ethiopia particularly in the fasting season. Cooking trend of the society can influence the nutrients to be retained after thermal treatment of green leafy vegetables in which ascorbic acid would be very vulnerable to loss. The extent of the loss of ascorbic acid depends upon variations in cooking methods and periods. Open-pan cooking and pressure cooking are the common household processing methods practiced in the rural and urban residences of Ethiopia, respectively. Cooking leafy vegetables at high temperature destroys ascorbic acid since it easily leaches into the cooking water being a water-soluble vitamin. The extent of the loss of ascorbic acid depends upon variations in cooking methods and periods [15].

Limited works have been carried out on the degradation of ascorbic acid in cabbage and Ethiopian green collard with respect to open-pan and pressure cooking methods. Being informed about these leafy vegetable cooking methods and their impact on vitamin loss might make the consumer more aware on how to optimize the nutrients obtained during a meal. Thus, the aim of this study was to examine the effect of the two cooking methods on the degradation of ascorbic acid in these green leafy vegetables.

2. Materials and Methods

2.1. Chemicals and Reagents. Metaphosphoric acid (MPA), L-ascorbic acid, glacial acetic acid, 2,6-dichlorophenol-indophenol, sodium acetate, and xylene were purchased from Micron Plc, Addis Ababa, Ethiopia. All the chemicals used were of analytical reagent grade.

2.2. Materials. Well-known and abundantly consumed Ethiopian green collard (*Brassica carinata*) and cabbage (*Brassica oleracea*) were collected from Bahir Dar city local market consulting Adet Agricultural Research Institute. All samples of raw material were packed in polyethylene bags. Samples were placed in an ice box and transported to Bahir Dar University, Institute of Technology, School of chemical and Food engineering Laboratories, for experimental work.

2.3. Thermal Processing Effect on Ascorbic Acid. For thermal processes studies, normal open-pan cooking and pressure cooking were selected as thermal processing methods. The ratios of sample to water were taken 1 : 2 and 1 : 4 (wt/vol) for pressure and open-pan cooking method, respectively. Cooking treatments were done at 5, 10, 15, 20, 25, 30, and 35 min cooking times under each method. The levels of vegetable to water ratio was set by pre-experimental trials and [16] working method. Cooking kettle for open-pan cooking and pressure cooker are used for thermal treatment device. Ten grams of samples were transferred into the cooking kettle and pressure cooker containing 40 mL distilled water. Samples were preheated at $96.7 \pm 3^{\circ}C$ and atmospheric pressure in open-pan cooking and $110^{\circ}C$ and 40 kpa in pressure cooker. Samples were withdrawn periodically and analyzed for ascorbic acid content.

2.4. Determination of Ascorbic Acid. Ascorbic acid was determined following the method stated by [16]. Clearly, standard indophenol's solution was prepared by dissolving 0.08 g of 2,6-dichlorophenol-indophenol in water diluted to 100 ml and filtered. The heat-treated leafy vegetable sample, along with the water, was ground to a paste with a minimum amount of 3% metaphosphoric acid in a mortar and pestle. Then, it was transferred into a 100 ml volumetric flask with the help of a funnel. The mortar and pestle were rinsed several times with small amounts of 3% metaphosphoric acid and added back to the volumetric flask. The volume was made up to 100 ml using 3% metaphosphoric acid, mixed thoroughly and then filtered through a filter paper. The filtrate (2 ml) was placed in a 50 ml stoppered conical flask followed by 2 ml of acetate buffer (pH 4.0, prepared by mixing 1 litre of 50% $CH_3COONa{\cdot}3H_2O$ with 1 litre of glacial acetic acid), 3 ml of Tillman's dye (2,6-dichlorophenol-indophenol), and 15 ml of xylene. It was shaken vigorously for 10 seconds, and the solvent was allowed to separate. The lower water layer was pipetted out, and the colour of the xylene layer was measured at 520 nm using a spectrophotometer. All the experiments were done in triplicate.

2.5. Statistical Analysis. Statistical analysis of the results was completed using JMPIN 5.1.0 statistical software and Microsoft Office Excel 2007. Data were expressed as means ± standard error (SE) of triplicate experiments. Differentiation between data sets was determined by the Student's t-test, and significant differences were considered when means of compared sets differed at $p < 0.05$.

3. Results and Discussion

3.1. Standard Curve Plot. First, a calibration graph was plotted preparing different known concentrations of pure ascorbic acid solutions (5, 10, 15, 20, 30, 35, 40, and 45 mg/100 ml) at room temperature and measuring absorbance at 520 nm wavelength.

The calibration curve was used to determine unknown concentrations of ascorbic acid of cabbage and Ethiopian green collard for each treatment designed under the two cooking methods (Figure 1).

3.2. Effect of Cooking Methods on Ascorbic Acid of Cabbage and Ethiopian Green Collard. Concentrations of ascorbic acid in fresh cabbage and Ethiopian green collard were found to be 33.76 ± 0.58 and 38.14 ± 0.19 mg/100 g, respectively confirming that both vegetables are good sources of vitamin C (ascorbic acid). These values were generally high for all the raw vegetables when compared with their processed counterparts.

Ascorbic acid contents of two green leafy vegetables as affected by two processing methods are shown in Figures 2 and 3. Ascorbic acid content decreased in both vegetable samples cooked by open-pan and pressure cooking methods. The cooking treatments cause a momentous impact on the ascorbic acid contents.

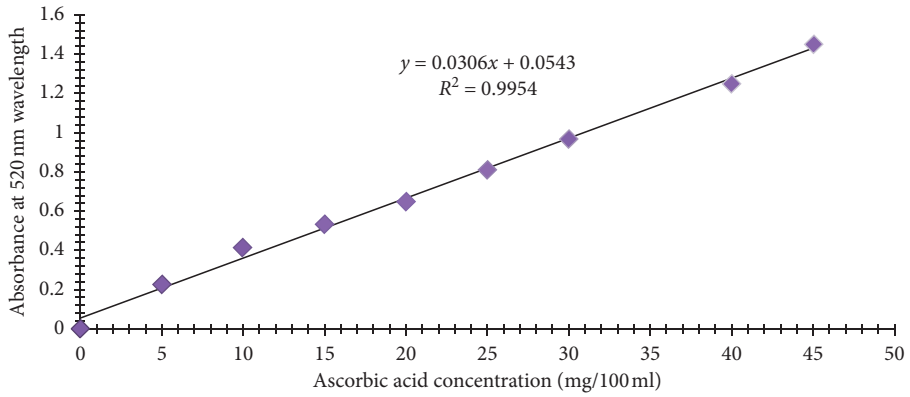

Figure 1: Calibration graph plot of pure ascorbic acid.

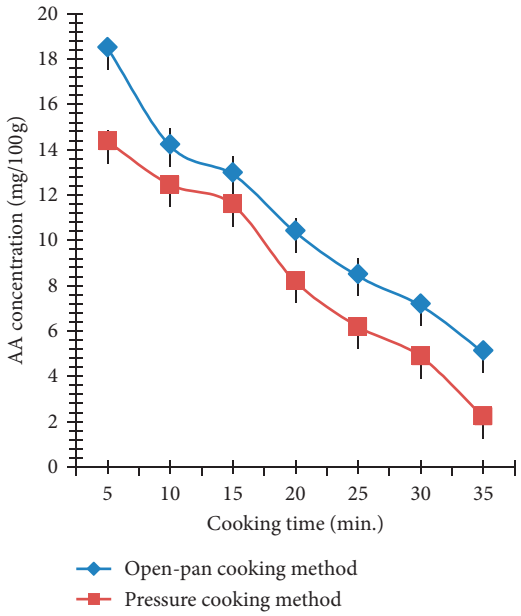

Figure 2: Effect of cooking methods on ascorbic acid loss of cabbage (error bars represent SE of the means).

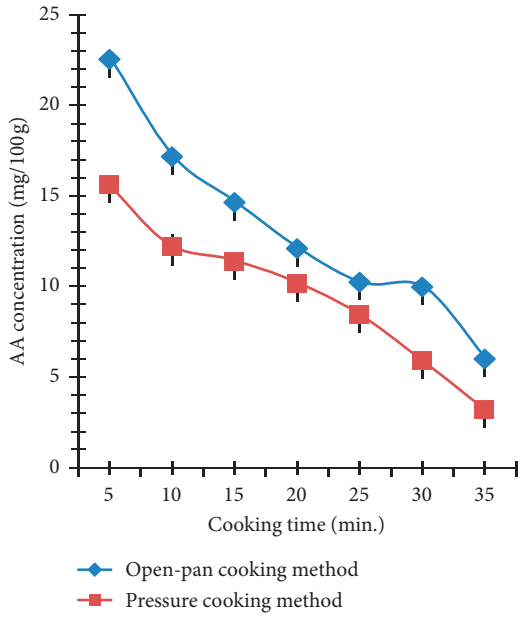

Figure 3: Effect of cooking methods on ascorbic acid loss of Ethiopian green collard (error bars represent SE of the means).

As shown in Figures 2 and 3, the trend of the graph indicates that ascorbic acid of cabbage and Ethiopian green collard decrease with increase in cooking time for both cooking methods. It also revealed that pressure cooking has a higher degradation rate on ascorbic acid of both green leafy vegetables.

The loss of ascorbic acid in green leafy vegetables is a function of the cooking methods and times employed for this study to them edible. Ethiopian green collard needed 10 min cooking time to be edible by pressure cooking and 25 min of open-pan cooking. The corresponding ascorbic acid loss becomes 68.2% in pressure cooking and a loss of 73.2% of ascorbic in open-pan cooking. More ascorbic acid loss was occurred in open-pan cooking.

Cabbage needed 10 and 20 minutes of cooking time to be edible in pressure and open-pan cooking methods, respectively. In pressure cooking, 63.1% ascorbic acid loss was found (Table 1). The loss was increased to 69.1% in open-pan cooking of cabbage.

Significant differences ($p < 0.05$) in ascorbic acid content were exhibited between treatments and cooking methods. Ascorbic acid content of Ethiopian green collard was decreased significantly ($p < 0.05$) with cooking time in the pressure cooking method.

In both leafy green vegetables, except 25 and 30 min cooking time of open-pan cooking (Table 2), ascorbic acid content was significantly decreased ($p < 0.05$) from 5–35 min treatment times.

Dramatic decreasing changes in the ascorbic acid contents were observed after cooking vegetables. The extent of ascorbic acid content reduction of leafy vegetables varied even though they were treated under the same cooking method. This is attributed to different vulnerabilities of cabbage and Ethiopian green collard due to their initial ascorbic acid content and enzymatic activities. Ethiopian green collard is more susceptible to thermal processing due to its lower activation energy [17].

Table 1: Retention (mg/100 g) and percent loss of ascorbic acid in cabbage under each cooking method.

Cooking time (min.)	Cooking method			
	Open-pan cooking*		Pressure cooking*	
	Retention	Loss (%)	Retention	Loss (%)
5	$18.52^{a} \pm 0.42$	45.1	$14.38^{a} \pm 0.48$	57.4
10	$14.24^{b} \pm 0.72$	57.8	$12.47^{b} \pm 0.32$	63.1
15	$13.00^{b} \pm 0.72$	61.5	$11.6^{b} \pm 0.23$	65.6
20	$10.43^{c} \pm 0.54$	69.1	$8.24^{c} \pm 0.11$	75.6
25	$8.52^{d} \pm 0.67$	74.8	$6.21^{d} \pm 0.37$	81.6
30	$7.21^{d} \pm 0.21$	78.6	$4.89^{e} \pm 0.14$	85.5
35	$5.14^{e} \pm 0.19$	84.8	$2.17^{f} \pm 0.29$	93.6

Data are expressed as means ± standard error (SE) of triplicate experiments. Ascorbic acid contents in fresh cabbage and *Ye'abesha Gomen* were 33.76 and 38.14 mg/100 g, respectively. Means in the column not connected by the same letter are significantly different at $p < 0.05$. *The effects of two cooking methods are significantly different within the column at $p < 0.05$ for both cabbage and Ethiopian green collard.

Table 2: Retention (mg/100 g) and percent loss of ascorbic acid in Ethiopian green collard under each cooking method.

Cooking time (min.)	Cooking method			
	Open-pan cooking*		Pressure cooking*	
	Retention	Loss (%)	Retention	Loss (%)
5	$22.54^{a} \pm 0.33$	40.9	$15.61^{a} \pm 0.47$	59.1
10	$17.16^{b} \pm 0.45$	55.0	$12.19^{b} \pm 0.70$	68.0
15	$14.64^{c} \pm 0.15$	70.9	$11.35^{bc} \pm 0.24$	70.2
20	$12.1^{d} \pm 0.37$	68.3	$10.15^{c} \pm 0.39$	73.4
25	$10.24^{e} \pm 0.34$	73.2	$8.43^{d} \pm 0.44$	77.9
30	$9.97^{e} \pm 0.47$	73.9	$5.91^{e} \pm 0.18$	84.5
35	$6.619^{f} \pm 0.35$	82.6	$3.84^{f} \pm 0.42$	89.9

Data are expressed as means ± standard error (SE) of triplicate experiments. Ascorbic acid contents in fresh cabbage and *Ye'abesha Gomen* were 33.76 and 38.14 mg/100 g, respectively. Means in the column not connected by the same letter are significantly different at $p < 0.05$. *The effects of two cooking methods are significantly different within the column at $p < 0.05$ for both cabbage and Ethiopian green collard.

Cooking methods and their duration affected the ascorbic acid content of both leafy vegetables, with an overall more profound effect by pressure cooking at similar cooking time. Longer cooking time enhanced the reduction of ascorbic acid in cabbage and Ethiopian green collard. The result of [18] research study showed that the cooking time had a higher influence on the ascorbic acid content of broccoli.

Loss as a result of open-pan cooking is justified since ascorbic acid is water-soluble and heat labile. Thus, ascorbic acid is easily leached into the boiling medium. Similar observations were reported on ascorbic acid of broccoli [14] and *Brassica rapa* [19].

Comparable results were reported by [20] where about 50% ascorbic acid retention was achieved in spinach cooked for 7 min. This indicates that short cooking duration may lead to a significantly higher retention of ascorbic acid. Retention of only 4–8% ascorbic acid has been found in spinach and amaranth leaves cooked for 30 min in an open-pan cooking [21]. The results of this study deviate from what [22] found for spinach, where the retention of ascorbic acid following cooking for 12 min was approximately 5%. The range of ascorbic acid retentions reported by different researchers during cooking may be attributed to different amounts of initial ascorbic acid in leafy green vegetables and also to the conditions used during storage and cooking. Shorter cooking times, less exposure of material to atmospheric oxygen, not chopping leaves prior to cooking, and lower water/vegetable ratios should all result in greater retention of the vitamin during cooking [23].

Sixty percent loss of ascorbic acid is reported in average in spinach through boiling and 58% through pressure-cooking [24]. It was found that boiling for 6 minutes caused 64.45% decrease in broccoli, 70.74% in white cabbage, and 66.82% in cauliflower [25].

4. Conclusion

Cabbage and Ethiopian green collard are the potential sources of health-promoting nutrients; ascorbic acid has been lost due to uncontrolled cooking methods. The research work aimed to examine ascorbic acid reduction trend in cabbage and Ethiopian green collard employing two cooking methods: open-pan and pressure cooking. The loss of ascorbic acid in Ethiopian green collard and cabbage is a function of the cooking methods and duration. As the results exhibit, the ascorbic acid content of the green leafy vegetables decreased under all cooking times of the two cooking methods employed, with greater losses occurring with pressure cooking at similar cooking duration.

Cooking of cabbage and Ethiopian green collard is expected for better safe consumption, and the cooking time required to make them edible is highly needed with minimum loss of ascorbic acid.

Well-cooked and edible Ethiopian green collard was obtained at 10 minutes of cooking time by the pressure cooking method with 31.8% ascorbic acid retention from its initial content. However, open-pan cooking needed longer cooking time of 25 minutes with 26.8% retention of ascorbic acid. Cabbage needed less cooking time (5 minutes of cooking time advantage) than Ethiopian green collard in open-pan cooking methods with 4.1% more ascorbic acid retention. Cooking time of 10 and 20 min were enough to obtain well-cooked and edible cabbage with 36.9% and 30.9% ascorbic acid retention using pressure and open-pan cooking, respectively.

Overall, the pressure cooking method provided higher ascorbic acid retention of 36.9% in cabbage and 31.8% in Ethiopian green collard to make them safe and edible. It also required short cooking time for having well-cooked and edible green leafy vegetable.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

The research was funded by Bahir Dar Institute of Technology. The laboratory facility provided by Bahir Dar Institute of Technology is admiringly acknowledged. The authors would like to express heartfelt gratitude to ANRS Agriculture Bureau for giving scientific names of studied green leafy vegetables and advising from the agricultural view point.

References

[1] C. Miglio, E. Chiavaro, A. Visconti, V. Fogliano, and N. Pellegrini, "Effects of different cooking methods on nutritional and physicochemical characteristics of selected vegetables," *Journal of Agricultural and Food Chemistry*, vol. 56, no. 1, pp. 139–147, 2008.

[2] Y. H. Hui, S. Ghazala, D. M. Gharam, K. D. Murrell, and W.-K. Nip, *Handbook of Vegetable Preservation and Processing*, Marcel Dekker, New York, NY, USA, 2004.

[3] R. Earle and M. Earle, *Fundamentals of Food Reaction Technology*, Leatherhead International Limited, London, UK, 2003.

[4] A. D. T. Fabbri and G. A. Crosby, "A review of the impact of preparation and cooking on the nutritional quality of vegetables and legumes," *International Journal of Gastronomy and Food Science*, vol. 3, pp. 2–11, 2016.

[5] U. Tiwari and E. Cummins, "Factors influencing levels of phytochemicals in selected fruit and vegetables during pre- and post-harvest food processing operations," *Food Research International*, vol. 50, no. 2, pp. 497–506, 2013.

[6] L. C. R. Dos Reis, V. R. de Oliveira, M. E. K. Hagen, A. Jablonski, S. H. Flôres, and A. de Oliveira Rios, "Effect of cooking on the concentration of bioactive compounds in broccoli (*Brassica oleracea* var. Avenger) and cauliflower (*Brassica oleracea* var. Alphina F1) grown in an organic system," *Food Chemistry*, vol. 172, pp. 770–777, 2015.

[7] R. Bongoni, R. Verkerk, B. Steenbekkers, M. Dekker, and M. Stieger, "Evaluation of different cooking conditions on broccoli (*Brassica oleracea* var. italica) to improve the nutritional value and consumer acceptance," *Plant Foods for Human Nutrition*, vol. 69, no. 3, pp. 228–234, 2014.

[8] T. S. Kahlon, R. R. Milczarek, and M.-C. M. Chiu, "In vitro bile acid binding of mustard greens, kale, broccoli, cabbage and green bell pepper improves with sautéing compared with raw or other methods," *Food and Nutrition Sciences*, vol. 3, no. 7, pp. 951–958, 2012.

[9] A. Mahn and A. Reyes, "An overview of health-promoting compounds of broccoli (*Brassica oleraceavar*) and the effect of processing," *Food Science and Technology International*, vol. 18, no. 6, pp. 503–514, 2012.

[10] G. B. Martínez-Hernández, F. Artés-Hernández, P. A. Gómez, and F. Artés, "Quality changes after vacuum-based and conventional industrial cooking of kailan-hybrid broccoli throughout retail cold storage," *LWT—Food Science and Technology*, vol. 50, no. 2, pp. 707–714, 2013.

[11] D. C. Murador, D. T. da Cunha, and V. V. de Rosso, "Effects of cooking techniques on vegetable pigments: a meta-analytic approach to carotenoid and anthocyanin levels," *Food Research International*, vol. 65, pp. 177–183, 2014.

[12] N. Pellegrini, E. Chiavaro, C. Gardana et al., "Effect of different cooking methods on color, phytochemical concentration, and antioxidant capacity of raw and frozen brassica vegetables," *Journal of Agricultural and Food Chemistry*, vol. 58, no. 7, pp. 4310–4321, 2010.

[13] A. A. M. Poelman, C. M. Delahunty, and C. de Graaf, "Cooking time but not cooking method affects children's acceptance of Brassica vegetables," *Food Quality and Preference*, vol. 28, no. 2, pp. 441–448, 2013.

[14] G.-F. Yuan, B. Sun, J. Yuan, and Q.-M. Wang, "Effects of different cooking methods on health-promoting compounds of broccoli," *Journal of Zhejiang University Science B*, vol. 10, no. 8, pp. 580–588, 2009.

[15] K. Bembem and B. Sadana, "Effect of cooking methods on the nutritional composition and antioxidant activity of potato tubers," *International Journal of Food and Nutritional Sciences*, vol. 2, no. 4, pp. 26–30, 2014.

[16] N. P. Bineesh, R. S. Singhal, and A. B. Pandit, "A study on degradation kinetics of ascorbic acid in drumstick (*Moringa olifera*) leaves during cooking," *Journal of the Science of Food and Agriculture*, vol. 85, no. 11, pp. 1953–1958, 2005.

[17] G. Ashine and T. Andargie, "Mathematical modelling of thermal degradation kinetics of ascorbic acid in *Brassica carinata*," *Science, Technology and Arts Research Journal*, vol. 4, no. 1, pp. 115–119, 2015.

[18] D. Zhang and Y. Hamauzu, "Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking," *Food Chemistry*, vol. 88, no. 4, pp. 503–509, 2004.

[19] M. Francisco, P. Velasco, D. A. Moreno, C. García-Viguera, and M. E. Cartea, "Cooking methods of Brassica rapa affect the preservation of glucosinolates, phenolics and vitamin C," *Food Research International*, vol. 43, no. 5, pp. 1455–1463, 2010.

[20] B. P. Klein, C. H. Y. Kuo, and G. Boyd, "Folacin and ascorbic acid retention in fresh raw, microwave, and conventionally cooked spinach," *Journal of Food Science*, vol. 46, no. 2, pp. 640-641, 1981.

[21] S. K. Yadav and S. Sehgal, "Effect of home processing on ascorbic acid and ?-carotene content of spinach (*Spinacia oleracia*) and amaranth (*Amaranthus tricolor*) leaves," *Plant Foods for Human Nutrition*, vol. 47, no. 2, pp. 125–131, 1995.

[22] A. Kala and J. Prakash, "Nutrient composition and sensory profile of differently cooked green leafy vegetables," *International Journal of Food Properties*, vol. 7, no. 3, pp. 659–669, 2004.

[23] O. O. Babalola, O. S. Tugbobo, and A. S. Daramola, "Effect of processing on the vitamin C content of seven Nigerian green leafy vegetables," *Advanced Journal of Food Science and Technology*, vol. 2, no. 6, pp. 303–305, 2010.

[24] D. Rumm-Kreuter and I. Demmel, "Comparison of vitamin losses in vegetables due to various cooking methods," *Journal of Nutritional Science and Vitaminology*, vol. 36, pp. 7–15, 1990.

[25] M. H. A. Shams El-Din, M. M. Abdel- Kader, S. K. Makhlouf, and O. S. Mohamed, "Effect of some cooking methods on natural antioxidants and their activities in some Brassica vegetables," *World Applied Sciences Journal*, vol. 26, no. 6, pp. 697–703, 2013.