



Effect of Different Cooking Methods on the Concentration of Vitamin C in Cowpea Vegetable (*Vigna unguiculata*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Vitamin C is a water-soluble vitamin widely distributed in nature, mostly rich in fresh fruits and green leafy vegetables. The amount of Vitamin C in a given food depends on soil condition, climate in their area of growth, storage condition after harvest, and methods of preparation. Much amount of Vitamin C in vegetables is lost during cooking and there are still limited information on the impact of different cooking methods on the vitamin C content in leafy vegetable like cowpea vegetable (*Vigna unguiculata*). It is upon this background that this study aimed to determine the concentration of Vitamin C in cowpea vegetable when cooked using different cooking methods.

Methodology: Vitamin C concentration in a solution of cowpea vegetable cooked by different cooking methods (boiling, steaming and microwave methods) was determined by a redox titration using iodine in the presence of starch indicator. This was conducted at Busitema University, Faculty of Science and Education, Biology Laboratory in Uganda.

Results: The study revealed that cooking cowpea vegetable using microwave yields the highest

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concentration of vitamin C (154.8 mg/L), followed by steaming (142.9 mg/L) and boiling yielding the least concentration of vitamin C (130.4 mg/L).

Conclusion: The concentration of vitamin C obtained by the three methods of cooking cowpea vegetable has shown that microwaving method of cooking yields the highest concentration of vitamin C followed by steaming method and finally boiling. Further studies should be done to explain the variation of vitamin C concentration in cowpea vegetable when cooked using the above cooking methods. Similar studies should be conducted on other leafy vegetables which are potential sources of Vitamin C.

Keywords: *Vigna unguiculata*; cowpea vegetable; cooking methods; boiling; steaming; microwaving; vitamin C concentrations.

1. INTRODUCTION

Vitamin C, also known as ascorbic acid, is a water-soluble vitamin required for several functions in the human body [1]. Its chemical formula is C₆H₈O₆ [2]. "Vitamin C plays an important role in forming collagen, a protein that gives structure to bones, muscles, and blood vessels; in blocking the formation of nitrosamines, potentially cancer-causing compounds; in increasing the absorption of iron; in stimulating the excretion of lead; and in promoting resistance to infection" [3]. "Also, it is a highly effective antioxidant, acting to lessen oxidative stress" [4]. "The clinical importance of vitamin C relates principally to its role as a cofactor in some enzyme reactions involved in collagen synthesis, the dysfunction of which disrupts connective tissue integrity, resulting in impaired wound healing and capillary bleeding" [5]. The ultimate sign of vitamin C deficiency in the diet is development of scurvy, a malnutrition condition that presents with bruising, bleeding gums, weakness, fatigue, and rash, among others [6]. "Previous studies from meta-analysis show that each 0.2 serving per day increase in green leafy vegetable intake was associated with a 13% lower risk of type 2 diabetes" [7]. "However, human bodies cannot synthesize vitamin C and it must be obtained either from diet or dietary supplements" [8]. "Vitamin C is widely distributed in nature, mostly rich in fresh fruits and green leafy vegetables such as guava, mango, tomato, cabbage, green paper, and *Vigna spp.*, among others" [9]. "The amount of vitamin C in food of plant origin depends on the variety of the plant, soil condition, climate in which they grow, time after the harvest, fruit storage conditions and methods of preparation" [10]. Studies have shown that vitamin C is also lost when cooking depending on the degree of heating, surface area exposed to water, oxygen, pH and the presence of transitional metal [11]. This raises a lot of questions on what method of cooking vegetables preserves a good quantity of

vitamin C since most vegetables are commonly cooked before being consumed. This study, thought to investigate the effects of three different cooking methods (i.e., steaming, microwaving, and boiling) on the vitamin C content of cowpea vegetable. The evaluation of these effects of cooking methods on the concentration of vitamin C on cowpea vegetable would provide the consumers of this food the most appropriate cooking methods that they could use and retain a relatively high amounts of vitamin C.

2. METHODOLOGY

2.1 Cooking Methods and Equipment Used

Boiling method is a cooking method where the cowpea vegetable submerged in water was heated using gas cooker (Multi-Function Electric Cooker, UGMC-108) until the boiling point was attained (i.e., the temperature at which the liquid changes from liquid phase to vapour phase when the vapor pressure of the liquid is equal to the atmospheric pressure exerted on the liquid).

Steaming method is a moist-heat method of cooking that works by boiling water which vaporizes into steam; it is the steam that carries heat to the food, hence cooking it. Unlike boiling where the cowpea vegetable was submerged in water, with steaming the vegetable is kept separate from the boiling water but comes into direct contact with the hot steam. In this method, (Geepas 3-Tier Food Steamer, GFS63025) was used to steam the cowpea vegetable.

In the microwave method of cooking, microwave oven (LG NeoChef Microwave Oven, MH6336GIB) cooks food using waves of energy (electromagnetic radiations) in the short-wave frequency range. These waves are remarkably selective, primarily affecting water and other molecules that are electrically asymmetrical, one end positively charged and the other negatively

charged. Microwaves cause these molecules to vibrate and quickly build up thermal (heat) energy that ends up cooking the food. This method required the cowpea vegetable to be submerged in water.

2.2 Preparation of Starch Indicator

Soluble starch (0.5 g) was weighed and 50ml of nearly boiling (~100°C) water was added to in a 100ml conical flask, stirred to dissolve and then cooled before usage.

2.3 Preparation of Iodine Solution the Standard Solution

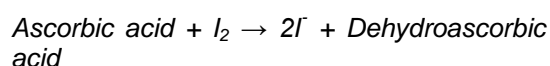
0.85 g of potassium iodide (KI) and 0.5g of iodine crystal were dissolved in 50 ml of distilled water in a 250 ml beaker. The solution was then made-up to the final volume of 250 ml with distilled water resulting in 0.005 molar iodine solutions.

2.4 Procedure for Determining Vitamin C Concentration in *Vigan Unguiculata*

Fifty (50) g of cowpea vegetable leaves were cut into smaller pieces and cooked by the three different methods under investigation: boiling, steaming and microwaving for a period of 0, 5, 10, 15, 20, 25 and 30 minutes. The juice extracts were obtained by blending different cooked samples with 200ml of distilled water using a blending machine (Saachi Blender, NL-BL-4361-WH) for 2 minutes. The blended samples were filtered using a sieve and the filtrate was put in different 250ml beakers for each cooking method each containing 200 mL of the extract. Twenty-five (25) mL of the sample were pipetted in a clean 250 mL conical flask and 20 drops of 1% starch indicator were added. The sample was titrated with 0.005 molar iodine solutions until the endpoint was reached (i.e., the point at which the stable traces of blue-black color is formed due to the formation of iodine-starch complex) and the volume of the iodine solution (standard solution) used in the titration was recorded.

2.5 Determination of Vitamin C Concentration in *Vigan unguiculata*

Iodine solution was used as the standard solution to determine the unknown concentrations of vitamin C in the different cooking methods using the reaction equation and the formula below.



$$[C_6H_8O_6] = \frac{[I_2] \times \text{Av. Vol of } I_2}{\text{Vol of } C_6H_8O_6}$$

2.6 Data Analysis

One-way ANOVA was used to determine the significance of the statistical differences in the concentrations of vitamin C between the three different methods of cooking: boiling, steaming, and microwaving and significance was accepted at $P \leq 0.05$. Pearson's product-moment correlation coefficient (r) was used to determine the relationship between time and concentrations of Vitamin C in cowpea vegetable for the three methods of cooking. The influence of time as a factor of determination of the concentration of vitamin C for the three methods of cooking was predicted using the coefficient of determination (r^2).

3. RESULTS

3.1 Effects of Cooking Methods on the Concentrations of Vitamin C in Cowpea Vegetable

The results obtained showed that there is variation in the concentration of Vitamin C in cowpea vegetable when subjected to the three different cooking methods. The highest concentration of Vitamin C is found to be in the microwaving method of cooking (154.8 mg/L), followed by steaming (142.9 mg/L) and boiling (130.4 mg/L), (Fig. 1 A, $F(7) = 5.85$, $p = .011$). The concentration of vitamin C in the control (uncooked) was higher (163 mg/L) compared to those of the cooking methods because the extract used in the control experiment was obtained from a fresh sample of cowpea vegetable without subjecting to cooking. The gradual decrease in the concentration of vitamin C was observed in all three methods of cooking over 30 minutes (Fig. 1 B).

3.2 Impact of Cooking Time on the Concentration of Vitamin C in Cowpea Vegetable

There were strong negative correlations between the cooking time and concentrations of vitamin C in all three methods of cooking: boiling, $r(4) = -.92$, $p = .009$, steaming, $r(4) = -.85$, $p = .034$, and microwaving, $r(4) = -.89$, $p = .018$, (Fig. 2 A, B, and C). The cooking time significantly impacted the concentrations of vitamin C in all three cooking methods: boiling; $r^2 = .85$, $p = .009$, steaming; $r^2 = .72$, $p = .034$; microwaving, $r^2 = .79$, $p = .018$, (Fig. 2 A, B and C).

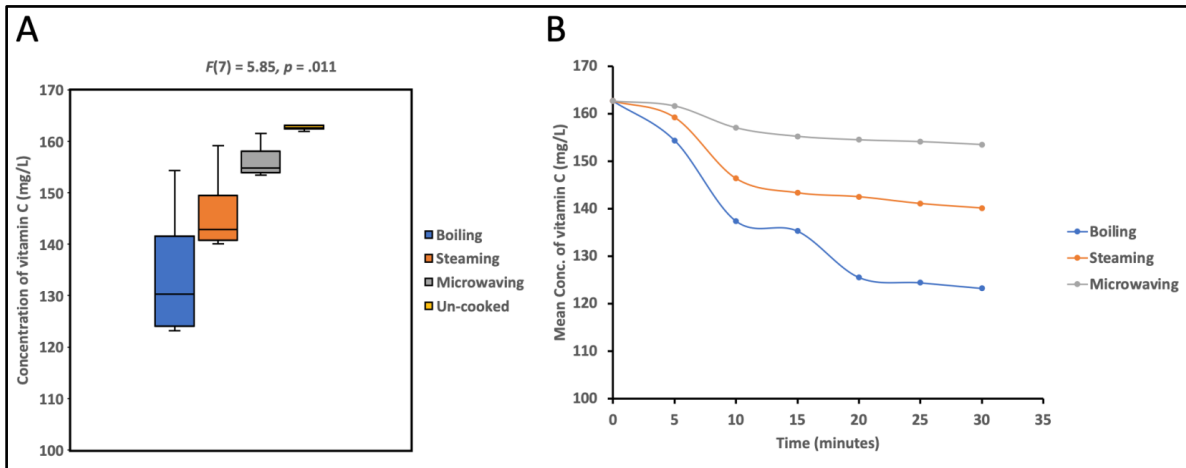


Fig. 1. Effects of cooking methods on the concentrations of vitamin C in cowpea vegetable
 Differences in concentrations of vitamin C after boiling, steaming, and microwaving the vegetable after 30 minutes (A), Effect of boiling, steaming and microwaving methods on the vitamin C concentration during the 30 minutes (B), The statistical significance of the differences between the methods of cooking was determined using One-way ANOVA ($F(7) = 5.85, p = .011$)

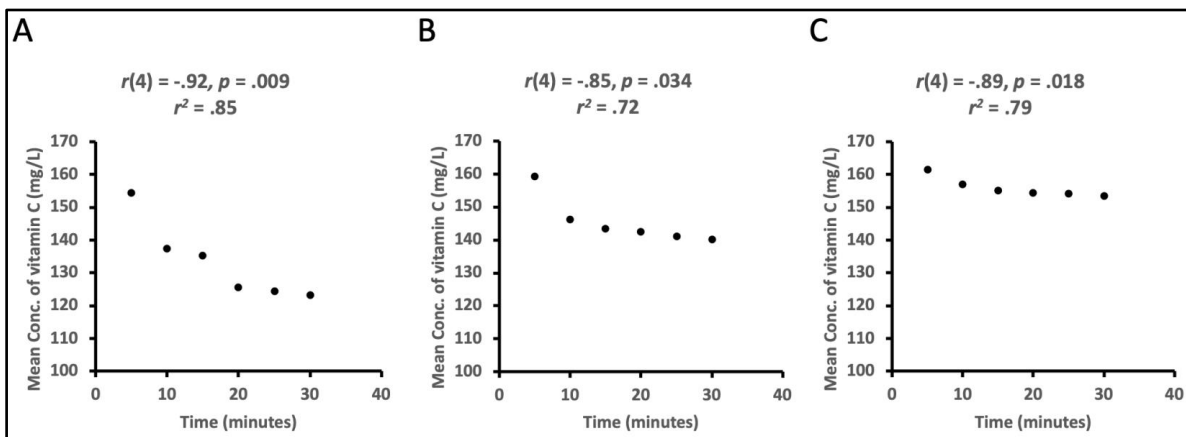


Fig. 2. Impact of cooking time on the concentration of vitamin C in cowpea vegetable
 Relationship between boiling time (A), steaming time (B) and microwaving time (C) and the concentration of vitamin C. Correlation coefficient between the cooking time and the concentration of vitamin C was determined using Pearson's product-moment correlation coefficient, (boiling, $r(4) = -.92, p = .009$; steaming, $r(4) = -.85, p = .034$; microwaving, $r(4) = -.89, p = .018$) and the influence of time as a factor of determination of the concentration of vitamin C for the three methods of cooking were predicted using coefficient of determination (boiling, $r^2 = .85, p = .009$; steaming, $r^2 = .72, p = .034$; microwaving, $r^2 = .79, p = .018$)

4. DISCUSSION

This study shows that boiling method of cooking results in the highest loss of vitamin C content in *Vigan unguiculata* vegetable compared to steaming and microwaving methods of cooking. In a similar study conducted on broccoli by Zeng C. et al in 2013, it has also been observed that boiling results into highest loss of vitamin C content compared to steaming and microwave methods [3]. "The high loss of vitamin C content during boiling could be attributed to the fact that vitamin C is very soluble in water and not stable

at high temperatures" [12]. "Loss of vitamin C occurs primarily by chemical degradation that involves the oxidation of ascorbic acid to dehydroascorbic acid (DHAA), followed by hydrolysis to 2,3-diketogulonic acid and further polymerization to form other nutritionally inactive products" [13]. "Thus, the boiling temperature could have inactivated most of the vitamin C in the vegetable, while the water would also wash away the vitamin C during the boiling process" [14]. Although boiling makes leafy vegetables like *Vigan unguiculata* less toxic and more palatable, it greatly affects their vitamin C contents [14].

Hence, a balance must be made between palatability and nutritional content by either reducing the boiling time or using alternative methods of cooking like steaming or microwaving that would retain more vitamin C than boiling method.

This study also demonstrated that microwaving method of cooking has the highest retention of vitamin C in the green leafy cowpea vegetable. This contradicts a finding of a similar study conducted by Zeng C. on some selected vegetables (broccoli, spinach, and lettuce) where out of the three methods of cooking, steaming resulted in the least loss of vitamin C contents [3]. This difference in the findings could be due to the fact that the loss of vitamin C in vegetables also depend on the particular vegetables. In different vegetables, there are varying rates of degradation of vitamin C contents by different methods of cooking [15].

Cowpea vegetable is one of the commonest vegetables routinely consumed to provide vitamin C requirement in the diet. However, microwaving method of cooking cannot be applicable in some rural areas due to the expensive nature of the microwaving equipment and inadequate electric power supply. The local community can therefore use the steaming method of cooking in order to obtain a considerable quantity and quality of vitamin C.

5. CONCLUSION

The study showed that cooking methods affect the concentration of vitamin C in cowpea vegetable with microwaving showing the highest retention of Vitamin C, followed by steaming and boiling showing the least retention of vitamin C. Further studies on other factors other than cooking methods that may affect the concentration of vitamin C in leafy vegetables such as cowpea vegetable are necessary. There is also a need to replicate this study using other leafy vegetables which contain vitamin C.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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