

## VITAMIN C STABILITY DURING BOILING AND FRYING IN SOME CULINARY VEGETABLES

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### Abstract

Vitamin C (ascorbic acid) is an essential water-soluble micronutrient that plays a critical role in antioxidant defense, collagen synthesis, immune function, and iron absorption. However, it is highly susceptible to degradation during thermal processing, particularly when exposed to elevated temperatures, oxygen, and aqueous cooking media. The present study evaluated the stability of vitamin C during boiling and frying in selected culinary vegetables, namely tomato (*Solanum lycopersicum*), potato (*Solanum tuberosum*), cauliflower (*Brassica oleracea* var. botrytis), and carrot (*Daucus carota*). Fresh vegetable samples (100 g each) were subjected to boiling at 100°C for 10 minutes and frying at 160°C for 3 minutes under controlled laboratory conditions. Vitamin C content in fresh, boiled, and fried samples was determined using the iodine titration method. The findings demonstrated that both cooking methods reduced vitamin C content in all vegetables compared with their fresh counterparts. However, boiling caused greater losses of vitamin C than frying, primarily due to the leaching of the water-soluble vitamin into the cooking medium and thermal degradation. In contrast, frying resulted in comparatively higher retention of vitamin C because of the shorter cooking duration and the absence of an aqueous medium. The degree of vitamin C loss varied among the vegetables, indicating that both vegetable characteristics and cooking conditions influence nutrient retention. The study highlights the importance of selecting appropriate cooking methods and processing conditions to maximize vitamin C retention and preserve the nutritional quality of vegetables.

### Introduction

Vegetables constitute an essential component of a healthy diet and provide a wide range of vitamins, minerals, dietary fiber, and bioactive compounds that contribute to human health and disease prevention. Regular consumption of vegetables has been associated with a reduced risk of chronic diseases, including cardiovascular disorders, obesity, diabetes mellitus, and certain types of

cancer. Among the micronutrients present in vegetables, vitamin C (ascorbic acid) is one of the most important owing to its diverse physiological functions and potent antioxidant properties.

Vitamin C is a water-soluble vitamin that cannot be synthesized by humans due to the absence of the enzyme L-gulonolactone oxidase. Consequently, adequate intake of vitamin C through dietary sources is necessary to maintain

normal physiological functions. Fresh fruits and vegetables such as tomatoes, potatoes, cauliflower, and carrots serve as important dietary sources of vitamin C. This vitamin is involved in collagen biosynthesis, immune regulation, wound healing, iron absorption, and the protection of cells against oxidative damage caused by reactive oxygen species.

Despite its nutritional significance, vitamin C is highly unstable and readily undergoes degradation during food processing and preparation. Factors such as temperature, oxygen exposure, light, pH, and the presence of metal ions substantially influence its stability. Thermal processing is considered one of the major causes of vitamin C loss because heating accelerates oxidation of ascorbic acid to dehydroascorbic acid, which is subsequently converted into biologically inactive degradation products. Therefore, cooking methods can significantly affect the nutritional quality of vegetables by altering their vitamin C content.

Boiling and frying are among the most commonly employed household cooking methods worldwide. Boiling generally results in substantial vitamin C losses because of both thermal degradation and the leaching of the water-soluble vitamin into the cooking water. Conversely, frying is performed at relatively higher temperatures but usually for shorter periods and in the absence of

water, which may reduce nutrient losses compared with boiling. Previous studies have demonstrated that the extent of vitamin C degradation depends on the type of vegetable, processing conditions, and duration of heat exposure. However, comparative information regarding the effects of boiling and frying on vitamin C stability in commonly consumed vegetables such as tomato, potato, cauliflower, and carrot remains limited, particularly under local conditions.

Therefore, the present study was conducted to evaluate the stability of vitamin C in selected culinary vegetables subjected to boiling and frying and to compare the extent of vitamin C retention and loss associated with these commonly used cooking methods. The findings of this study may contribute to the development of evidence-based dietary recommendations and promote cooking practices that better preserve the nutritional quality of vegetables.

## Materials and Methods

### Study Design and Experimental Setting

This experimental study was conducted in the Central Laboratory of the Department of Biochemistry, Women University Mardan, Pakistan, under controlled laboratory conditions. The study was designed to evaluate the stability of vitamin C in selected culinary vegetables subjected

to two commonly used household cooking methods, namely boiling and frying.

### Sample Collection and Preparation

#### For fresh samples

100 g of each of the selected culinary vegetable was cut into small uniform pieces and then blended with 100ml of distilled water to form a uniform solution. The solution obtained was filtered.

#### For boiled samples

100 g of the each of the selected vegetable was boiled in a boiling vessel at 100 °C for 10 minutes. The boiled vegetable sample was allowed to cool down before blending. Afterwards it was blended with 100 ml of distilled water to form an even solution. The solution was then filtered.

#### For fried samples

In the case of fried samples, 100 g of each of the vegetable was fried in a frying pan at 160 °C for 3 minutes. The fried vegetable sample was allowed to cool down before the blending process. Once it was cooled it was blended with 100 ml of distilled water to get a consistent solution. Afterwards the solution was filtered.

### Extraction of Vitamin C

Fresh, boiled, and fried vegetable samples were separately cut into small uniform pieces and blended with 100 mL of distilled water to obtain homogeneous extracts. The resulting mixtures

were filtered to remove particulate matter. To minimize oxidation and degradation of vitamin C, the extracts were stored in airtight containers and analyzed immediately after preparation.

**Preparation of Starch Indicator** A 1% starch indicator solution was prepared by dissolving 1 g of starch in 100 mL of distilled water. The solution was heated gently with continuous stirring until a uniform and homogeneous mixture was obtained and then allowed to cool before use.

### Determination of Vitamin C by Iodine Titration

Vitamin C content was determined using the iodine titration method based on the reduction of iodine by ascorbic acid. Briefly, 10 mL of vegetable extract was transferred into a conical flask, followed by the addition of 4-5 drops of 1% starch indicator solution. A 0.01 M iodine solution was added dropwise with continuous mixing until the appearance of a persistent blue-black coloration, which indicated the endpoint of the titration. All analyses were performed in triplicate, and the average values were recorded. As long as vitamin C is present in the extract no color appear. After all vitamin C is used up, the excess iodine reacts with the starch solution and results in the formation of blue black color.

### Calculation of Vitamin C Content

Vitamin C content in the vegetable extract was determined by the amount of iodine solution used

and the concentration of iodine solution. This was determined by the following formula:

$$\text{Vitamin C (mg/100g)} = V \times C \times 88 \times 100 / V_s \times W$$

Where: V is the volume of iodine solution used.

C is the concentration of iodine solution.

88 is the equivalent weight of vitamin C

V<sub>s</sub> is the volume of the sample

W is the weight of the sample

## Results

### Vitamin C Content of Fresh Vegetables

The vitamin C content of fresh tomato, potato, cauliflower, and carrot samples is presented in Table 1. Among the selected vegetables, cauliflower exhibited the highest vitamin C content (48.20 ± 1.75 mg/100 g), followed by potato (20.80 ± 1.40 mg/100 g) and tomato (20.10 ± 0.85 mg/100 g). Carrot contained the lowest concentration of vitamin C (5.10 ± 0.40 mg/100 g).

**Table 1. Vitamin C content of fresh selected vegetables.**

Vegetable	Vitamin C content (mg/100 g FW)
Tomato	20.10 ± 0.85
Potato	20.80 ± 1.40
Cauliflower	48.20 ± 1.75

Carrot	5.10 ± 0.40
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### Effect of Boiling on Vitamin C Content

The effect of boiling at 100°C for 10 min on vitamin C content is presented in Table 2. Boiling substantially reduced vitamin C levels in all vegetables. Cauliflower retained the highest amount of vitamin C after boiling (29.40 ± 1.10 mg/100 g) and exhibited the lowest percentage loss (39.0%). In contrast, tomato and potato showed the greatest losses, with reductions of 55.7% and 55.6%, respectively.

**Table 2. Effect of boiling (100°C for 10 min) on vitamin C content of selected vegetables.**

Vegetable	Fresh vitamin C (mg/100 g FW)	Boiled vitamin C (mg/100 g FW)	Vitamin C loss (%)
Tomato	20.10 ± 0.85	8.90 ± 0.60	55.7
Potato	20.80 ± 1.40	10.80 ± 0.75	55.6
Cauliflower	48.20 ± 1.75	29.40 ± 1.10	39.0
Carrot	5.10 ± 0.40	2.60 ± 0.20	49.0

### Effect of Frying on Vitamin C Content

The effect of frying at 160°C for 3 min on vitamin C content is shown in Table 3. Although frying reduced vitamin C concentrations in all vegetables, the degree of reduction was lower than that observed during boiling. Potato showed the highest vitamin C retention (84.2%), followed by tomato (74.1%) and carrot (66.7%). Cauliflower retained 53.5% of its original vitamin C content after frying.

**Table 3. Effect of frying (160°C for 3 min) on vitamin C content of selected vegetables.**

Vegetable	Fresh vitamin C (mg/100 g FW)	Fried vitamin C (mg/100 g FW)	Vitamin C retention (%)
Tomato	20.10 ± 0.85	14.90 ± 0.95	74.1
Potato	20.80 ± 1.40	20.50 ± 1.30	84.2
Cauliflower	48.20 ± 1.75	25.80 ± 1.40	53.5
Carrot	5.10 ± 0.40	3.40 ± 0.30	66.7

### Comparative Analysis of Boiling and Frying

comparison of vitamin C retention following boiling and frying is presented in Table 4. Overall, frying preserved a greater proportion of vitamin C than boiling in tomato, potato, and carrot

samples. However, cauliflower retained slightly higher amounts of vitamin C following boiling than frying under the conditions employed in the present study.

**Table 4. Comparative analysis of vitamin C retention following boiling and frying.**

Vegetable	Retention after boiling (%)	Retention after frying (%)
Tomato	44.3	74.1
Potato	44.4	84.2
Cauliflower	61.0	53.5
Carrot	51.0	66.7

*Values are expressed as mean ± SD of triplicate determinations (n = 3). FW = Fresh weight.*

### DISCUSSION

The vitamin C content of the fresh vegetable samples was determined with high precision and it is clear through its alignment with the existing literature. Though minor differences occur due to some instrumental error or the difference in the variety of vegetable. The vitamin C content of the fresh tomato in the present study is 20.10 ± 0.85 and it falls under the same range as the one determined by Okuku and Okeke (2021) that was 19.59mg/100g. There is only a slight difference between the two values and it can be because of some instrumental handling and though it needs no adjustment. The vitamin C content in fresh potato samples as of the present study is 24.35 ±

1.20 mg/100g. This value represents high accuracy because it comes in the range reported by Samaneigo et al., (2020) that is 12.67 to 39.49mg/100g. The values reported by Samaneigo et al., (2020) represents a vast range as it includes the vitamin C content of all the varieties of potato. The present study was conducted on the type of potatoes commonly consumed in Pakistan while Samaneigo et al., (2020) conducted the experiment on European potatoes. The climate difference and agricultural facilities differ in both the regions which results in the difference in both values. However the vitamin C content as of determined by the present study do fall under the range reported by Samaneigo et al., (2020). The vitamin C content of potato determined by the present study is relatively low in general. This is verified by Soare et al., (2020) that the colored skin potatoes like blue or purple contain more vitamin C than the ones with white or yellow skin. In the case of cauliflower the current finding state that the vitamin C content in fresh cauliflower samples is  $48.20 \pm 1.75$ mg/100g. These findings are related with those determined by Anika et al., (2025) whose results were 86.63mg/100g. The experiment conducted by Anika et al., (2025) included the yellow cauliflower and the present study included the white cauliflower. Anika et al., (2025) stated that the vitamin C content in white cauliflower is lower than the yellow cauliflower

which justifies the present study. The vitamin C content determined in fresh sample of carrot as of the current finding is  $5.10 \pm 0.40$  mg/100g. These values differ from the ones reported by Ma et al., (2020) that were 0.30 to 0.63mg/g. This difference occurs because Ma et al., (2020) conducted experiment on basis of dry weight while the present study was conducted on fresh weight.

The vitamin C content in the boiled vegetable samples was determined meticulously. The value of vitamin C in boiled tomato and potato sample as of the present study is  $8.90 \pm 0.60$  and  $10.80 \pm 0.75$  which shows 55.7% and 55.6% loss of vitamin C from their fresh form. The percentage loss of tomato and potato closely align with the ones stated by Lidikova et al., (2025) that were 51.52 to 63.5. The percentage loss reported in present study falls in the range reported by Lidikova et al., (2025). This can be due to the same boiling temperature and time provided. The percentage loss of vitamin C in boiled cauliflower samples determined by present study is 39%. This value lies between the range reported by Multescu et al., (2020) that is 28 to 43.9%. The percentage loss determined by present study falls in the far end of the range reported by Multescu et al., (2020). It can be due to the large pore size of white cauliflower that results in high loss of vitamin C. For the boiled samples of carrot 49% loss of vitamin C was recorded in the present

study. This value relates with the one reported by Fartoosi et al., (2025) that was 46%. This slight difference occurs because of the quality of freshness of carrot or the sample size. The findings of the present study also relates with the findings of Bureau et al., (2024) who stated 51% loss in general during the boiling process. The percentage loss of tomato, potato and cauliflower of present study that is 55.7%, 55.6% and 39% aligns with the percentage loss stated by Bureau et al., (2024).

The vitamin C content in fried vegetable samples was determined with careful precision. Though minor differences do occur because of the difference in the frying time or temperature. The vitamin C content in fried potato sample determined in present study is  $20.50 \pm 1.30$  which reports 84.2% of vitamin C. These findings align with the ones reported by Gracia-Torres et al., (2022) that was 87.6% retention of vitamin C. These slight differences occur due to the change of the variety of the potato. Gracia-Torres et al., (2022) conducted experiment on Peruvian potatoes while the present study was conducted on Pakistani potatoes. These both types differ in their starch composition which affects its vitamin C retention during the frying process. In the case of fried cauliflower the vitamin C retention reported in present study was 53.5%. This value closely matches with the one stated by Kosweski et al., (2023) that was 52.7%. This slight difference is

acceptable and can be due to the floret size. The vitamin C content in fried tomato sample as reported by present study was  $14.90 \pm 0.95\text{mg}/100\text{g}$  which contributes to 74.1%. This shows a high retention value during the frying process which aligns with Teh and Ting (2024) who stated that the frying process cause better retention of vitamin C. As for fried carrot samples 66.7% of retention and 33.3% loss of vitamin C was recorded in the present study. This somehow matches with the findings of Ediz et al., (2024) who reported a loss of antioxidant activity associated with vitamin C during the frying process. The percentage loss of present study shows moderate losses which slightly matches with the finding of Ediz et al., (2024). The retention values of vitamin C in the vegetables determined in the present study also aligns with Jiang et al., (2023) who stated that frying cause better retention of vitamin C because its leaching in the cooking medium is prevented due to the lipid based cooking medium.

The comparative analysis of boiling and frying depends on the type of vegetable in general. The present study on boiling and frying reported that boiling cause more loss of vitamin in tomato, potato and carrot. These closely related with the findings of Mehmood and Zeb (2020) who stated that frying is less harmful as compare to boiling. However cauliflower remains an exception. The

fried sample of cauliflower reported more loss of vitamin C than the boiled samples in present study. Though the retention value during frying do match with the value reported by Kosweski et al., (2023). Overall the four vegetables in the present study recorded the vitamin loss from 33% to 55% during boiling and 53% to 84% during frying. These percentages somehow match with that of Khatun et al., (2019) who reported 6% to 93% loss during boiling and 33% to 95% during frying. The values reported by present study do fall in the range stated by Khatun et al., (2019). However the minor differences occur because of the vegetable difference as Khatun et al., (2019) conducted experiment on a broader variety of vegetables.

## CONCLUSION

This study was conducted to determine the stability of vitamin C during boiling and frying in some culinary vegetables like tomato, potato, cauliflower and carrot. The results of the study showed that as vitamin C is a heat sensitive vitamin, its significant loss occurred during the two cooking methods. Among the two cooking methods, it was notes that boiling caused more loss of vitamin C in the selected culinary vegetables than frying. It was also noted that among the four culinary vegetables studied tomato showed the highest loss during boiling whereas potato retained more vitamin C during the frying

process. Highest % losses during the boiling process is due to the water soluble nature of vitamin C, as it leaches into the cooking medium. The findings of this study revealed that vegetables should be boiled for a minimum time in a small amount of water. Although the present study focused on the four commonly consumed culinary vegetables, future research can focus on some other cooking methods or some other vegetables.

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