

# Effect Of Various Cooking Methods On Vitamin C Levels In Broccoli Smoothies

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**ABSTRACT:** This study examined vitamin C levels in smoothies made with raw versus cooked broccoli. Humans are unable to synthesize or store vitamin C and must obtain it through their daily diet. Vitamin C is a powerful antioxidant and an essential vitamin in the human diet. Broccoli is a vegetable with one of the higher levels of vitamin C versus even oranges, strawberries and spinach. Three common cooking methods used in the United States, steaming, grilling and baking were evaluated. Vitamin C levels were measured using 2,6-dichlorophenol-indophenol (DCPIP). This experiment found significantly lower levels of vitamin C in the smoothie prepared with the uncooked broccoli. The smoothie prepared with the steamed broccoli had the highest levels of vitamin C. Currently, most people prepare smoothies with raw vegetables. Using some cooked vegetables may increase specific nutrient content in smoothies and warrants further study.

**Key Words:** ascorbic acid, baked, broccoli, diet, grilled, nutrition, steamed, Vitamin C

## 1. INTRODUCTION

Vitamin C is a water-soluble vitamin and has the chemical name ascorbic acid. It is a powerful antioxidant and an essential vitamin in the human diet. Vitamin C is required for biosynthesis of collagen, neurotransmitters and protein metabolism. Humans, unlike most animals, are unable to synthesize or store vitamin C and therefore, must obtain it through their daily diet [2]. Many Americans are not consuming the daily recommended number of servings of vegetables and fruits. In the United States, 14% of males and 10% of females were reported deficient in vitamin C in data from 1988 to 1994 [2]. Deficiency in vitamin C can lead to disease and poor health [4]. Severe deficiency of vitamin C can lead to a medical condition called scurvy. Signs and symptoms of scurvy include fatigue, increased fractures, and bleeding under the skin and around the gums. Mild to moderate deficiency of vitamin C can contribute to easy bruising, slowly healing wounds, painful joints, osteoporosis, poor immunity and chronic inflammation [5]. Fruits and vegetables are the best sources of vitamin C. The daily value of vitamin C recommended by the Food and Drug Administration is 75 mg for adult females and 90 mg for adult males [2]. Foods with high vitamin C levels include citrus fruits, potatoes, and some vegetables. The US Department of Agriculture reports higher levels of vitamin C in raw broccoli versus vitamin C levels in oranges, strawberries and spinach [2]. Ascorbic acid (vitamin C) levels can be measured in food by use of an oxidation-reduction reaction [7]. Ascorbic acid is a good reducing agent and therefore, it is easily oxidized. Methods for determining vitamin C levels involve titrating it against a solution of an oxidizing agent [5]. The most commonly used oxidizing agent to measure vitamin C levels is 2, 6-dichlorophenol-indophenol (DCPIP) [5]. The DCPIP is a dark blue color in neutral or basic solutions but changes to red with the addition of acids. Additionally, DCPIP becomes colorless with ascorbic acid [3]. Therefore, DCPIP can be used to test for the presence of vitamin C in foods. Processing, packaging, storage and cooking can affect vitamin C levels in foods. High temperatures in the presence of light and oxygen cause ascorbic acid to undergo a chemical reaction called oxidation which diminishes vitamin C levels. Since vitamin C is a water-soluble vitamin, cooking in high temperatures leaches vitamin C into the cooking water thus causing levels in cooked foods to diminish [6]. Therefore, vitamin C is easily

destroyed by heat and water, as well as exposure to air. Since vitamin C is easily reduced or destroyed by heat, cooking strongly affects vitamin C levels in foods [3]. Due to most cooking methods generally utilizing both high temperatures and water, vitamin C levels are decreased when foods are cooked. Understanding how nutrient levels, such as vitamin C levels, are affected by cooking methods can allow development of strategies to reduce the loss of nutrients when cooking food. Therefore, gaining knowledge on how cooking affects nutrient levels will allow preparation of foods which are better for health and well-being. The purpose of this study was to investigate the effects of three different specific cooking methods on the vitamin C levels in smoothies made using fresh broccoli. The effects of steaming, baking and grilling cooking methods on vitamin C levels in smoothies made using fresh broccoli were evaluated. This study evaluated which cooking method best preserved vitamin C levels in the cooked broccoli versus the fresh, uncooked broccoli when used to make smoothies. The hypothesis of this study was if the broccoli is cooked then the vitamin C levels will decrease compared to fresh, uncooked broccoli smoothies. The independent variable was the cooking method and the dependent variable was the amount of vitamin C in the sets of broccoli. The constants in this study were the source of the broccoli, the amount of broccoli used in each set, the time the broccoli was cooked with each method, and the volume of the chemical 2, 6-dichlorophenol-indophenol (DCPIP) used to determine levels of vitamin C. Expected outcomes were that steaming will produce the greatest decrease in vitamin C levels of fresh broccoli smoothies because vitamin C will be lost with the steam since it is water-soluble as well as through oxidation due to the high temperatures needed for steaming food [7]. In a study on effects of different cooking methods in China on health promoting compounds of broccoli, author Q. Wang studied steaming, microwaving, boiling, stir-frying, and stir-frying followed by boiling [8]. This study examined levels of vitamin C, total soluble proteins and soluble sugars. The authors found that the steaming cooking method produced the least significant decrease in vitamin C levels in broccoli [8]. In an Italian study, author N. Pellegrini studied boiling, steaming and frying cooking methods' effects on nutritional characteristics of carrots, zucchini, and broccoli. N. Pellegrini found that water-cooking treatments better preserved vitamin C levels in carrots and zucchinis [6]. The effect of heating on vitamin

C levels of five common vegetables in Nigeria were studied by authors I.A. Imran and peers. Carrots, pumpkin, green peas, pepper, and spinach were studied in this study. Broccoli was not evaluated in this study. This study found that the vitamin C levels decreased the most for all five vegetables with the longest heating times [4]. The main studies evaluating effects of cooking methods on vitamin C levels in broccoli specifically have been done in China and Italy. This study evaluated the effects of cooking methods

## 2. METHODOLOGY

Fresh organic broccoli was cleaned by removing the inedible parts and washing under cold tap water. The broccoli was then chopped into homogeneous pieces, leaving a stem of 25 mm. The broccoli was divided into equal portions each weighing 100 gm using a digital kitchen food scale. One portion of broccoli was retained raw, and the others were cooked using three different methods. Three common cooking methods used in the United States, baking, grilling and steaming were used to prepare the broccoli. Cooking methods which do not require direct immersion of broccoli in water were selected in order to eliminate water as a variable in the experiment. A Bosch 500 Series Single Wall Oven (Model # HBL541UC) was equilibrated to room temperature prior to each cooking trial. One 100 gm portion of cleaned broccoli was placed in the center of an 8 x 10-inch glass baking pan. The oven controls were set to bake at a temperature of 400 degrees Fahrenheit. The glass baking pan with the broccoli was placed in the oven for 10 minutes after the 400-degree oven temperature was reached. After 10 minutes in the oven, the glass pan with the broccoli was removed from the oven and placed at room temperature. The baking steps were repeated with a second and a third 100 gm portion of cleaned broccoli. A Calphalon 6-quart stainless steel vegetable steamer was utilized for steaming the broccoli. Tap water was placed in the lower portion of the steamer. The Calphalon steamer was placed on a Bosch 800 Series 5-Burner Stainless Steel Gas Range (Model # HG18054UC) burner turned on at medium heat. The tap water in the lower portion of the steamer was allowed to come to a boil. A 100-gm portion of broccoli was placed in the steamer insert after the water was boiling. The broccoli was allowed to cook in the steamer insert for 10 minutes. After 10 minutes, the broccoli was removed from the steamer insert and placed at room temperature. The steaming steps were repeated with a second and third 100 gm portion of cleaned broccoli. A Lodge Reversible Cast

commonly used in the United States on vitamin C levels in smoothies prepared with broccoli. This study eliminated using water in any of the cooking methods evaluated since vitamin C is water soluble and leaches into cooking water. Previous studies have not attempted to limit cooking methods based on use of water and have not studied vitamin C levels in smoothies made with cooked versus raw broccoli.

Iron 16.75-inch Grill/Griddle was utilized for grilling the broccoli. The grill was placed on a Bosch 800 Series 5-Burner Stainless Steel Gas Range (Model # HG18054UC) burner turned on at medium heat. Once the grill was heated, a 100-gm portion of broccoli was placed on the grill and allowed to cook for 10 minutes. After 10 minutes, the broccoli was removed from the steamer insert and placed at room temperature. The steaming steps were repeated with a second and third 100 gm portion of cleaned broccoli. To measure vitamin C levels, 2, 6-dichlorophenol-indophenol (DCPIP) was purchased from a medical supply store. The DCPIP method to measure vitamin C levels was selected because of its relative simplicity and easy access to the chemical. The 100-gm raw broccoli and each of the 100 gm cooked portions of broccoli were placed in 125 mL of water and placed in a Magic Bullet smoothie maker. The prepared smoothies made from each set of broccoli were placed in a bowl and allowed to stand for 30 minutes. Each of the prepared smoothies were placed using a pipette one drop at a time into a test tube containing 25 drops of DCPIP. The number of drops of the liquid extract needed to cause the DCPIP to change from blue to colorless was recorded. This was repeated for all the smoothies made from the raw broccoli and each cooked portion of broccoli. The data specifying the number of smoothie drops needed to change the DCPIP to colorless was observed and recorded. The experimental results were analyzed through a statistical analysis t-test to see if there was a significant difference between the cooking method versus raw broccoli and the vitamin C levels in the smoothies.

## 3. RESULTS

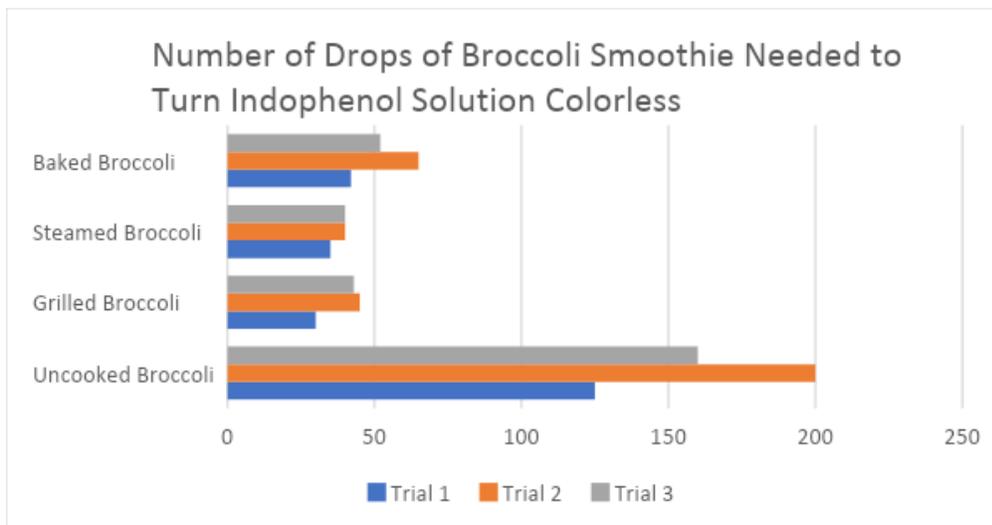
Results were recorded for each of the four sets of broccolis: uncooked, steamed, grilled and baked. Three trials of the experiment were completed to obtain three data sets. The number of drops of the broccoli smoothies needed to make the blue color of the indophenol solution in each test tube turn colorless was recorded.

**Number of Drops (from Pipette) of Broccoli Smoothie Needed to Turn Indophenol Solution Colorless**

**Table 1**

	Trial 1 drops	Trial 2 drops	Trial 3 drops	Average drops
Uncooked Broccoli	125	200	160	161.6
Grilled Broccoli	30	45	55	43.3
Steamed Broccoli	35	48	45	42.7
Baked Broccoli	42	65	40	49.0

Number of Drops of Broccoli Smoothie



The uncooked broccoli smoothies required significantly more drops to turn the indophenol solution colorless in all three trials. Since the indophenol solution turns colorless in the presence of vitamin C based on an oxidative-reductive reaction, these results support that the uncooked broccoli smoothies had the lowest levels of vitamin C. The steamed broccoli smoothies had the lowest number of drops to turn

the indophenol solution colorless in all three trials. These results support that smoothies made with steamed broccoli have significantly higher levels of vitamin C compared to smoothies made with uncooked broccoli. Smoothies made with all three methods of cooking, grilled, steamed and baked had higher levels of vitamin C than uncooked broccoli.

**Comparison Between Cooked and Uncooked Broccoli Vitamin C Levels**  
**Table 2**

Table Value	2.132
Calculated Value	8.867

Table 2 shows the comparison between cooked and uncooked broccoli. The research hypothesis states that uncooked broccoli would exhibit greater Vitamin C levels than cooked broccoli. The null hypothesis states that there would not be a difference in Vitamin C levels between cooked and uncooked broccoli. The alternative hypothesis states there would be a difference in Vitamin C levels between uncooked and cooked broccoli. The calculated value was higher than the table value for the comparison. This signifies that the null hypothesis was rejected, and the alternative hypothesis was not rejected. The research hypothesis was not supported.

**Conclusion**

In all three trials of the experiment, the uncooked broccoli smoothies required significantly more drops to turn the dark blue DCPIP solution colorless compared to the cooked broccoli samples. These results support that the uncooked broccoli smoothies had the lowest levels of vitamin C. The raw broccoli vitamin C levels were between 4 times to 6 times lower than the cooked broccoli vitamin C levels. The steamed broccoli had the overall highest vitamin C levels in all three trials. However, the vitamin C levels in the steamed, baked and grilled broccoli were fairly equal. This is supported by calculating the range for the data in the

trials. The range for the number of cooked broccoli smoothie drops needed to turn the DCPIP solution colorless in the three trials was 35 (30, 65). The range was 170 (30, 200) when the data sets for the uncooked and raw broccoli were evaluated together. This concludes that the research hypothesis was not supported by the data of the experiment. Data from studies done in the United States have generally concluded that raw vegetables are more nutritious than cooked vegetables. In an article from the United States Department of Agriculture (USDA), author Rosanna Chung evaluated boiling, steaming and frying cooking methods on the value of glucosinolates and vitamin C in broccoli. This study concluded that conventional cooking methods lead to the degradation of vitamin C in broccoli. Steaming was found to best preserve both vitamin C and glucosinolates in broccoli [1]. Chuli Zeng studied the effects of steaming, microwaving and boiling on vitamin C content of broccoli, spinach and lettuce. Zeng found loss of vitamin C using all three cooking methods for all three vegetables and concluded that eating raw vegetables is the best way to obtain vitamin C [9] A small number of studies have found that cooking may increase the release of some nutrients. In the first study, Qiao-mei Wang and colleagues in a 2009 study in China evaluated the effects of five different cooking methods on the nutritional values of

broccoli. Wang utilized steaming, microwaving, boiling, stir-frying and stir-frying followed by boiling to prepare the cooked broccoli. The nutrients in broccoli studied were vitamin C, chlorophyll, total soluble proteins and soluble sugars. This study found that all the cooking methods, except steaming, caused significant loss of vitamin C in broccoli. Overall, the steaming method had the best retention of the nutrients in cooking broccoli [8]. In a second 2008 study from Italy, Nicoletta Pellegrini evaluated the effects of three different cooking methods on the nutritional values of three vegetables. Pellegrini utilized boiling, steaming and frying to prepare carrots, zucchini, and broccoli. This study found that water cooking methods caused less loss of vitamin C in carrots and zucchini but not broccoli. The authors suggest that each vegetable has a cooking method that would be preferred to preserve the nutritional qualities [6]. The results of the current experiment support that the levels of heat involved in cooking broccoli as described do not destroy vitamin C levels in broccoli. All three cooking methods studied in this experiment did not involve broccoli being cooked directly in water. This criterion minimized the loss of vitamin C in the cooked broccoli samples due to loss in cooking water since vitamin C is water soluble. The increased vitamin C levels in the cooked broccoli samples versus the raw broccoli samples support that cooking broccoli releases vitamin C making it more bioavailable. Cooking is known to break down the thick cell walls of many plants, releasing the nutrients in them. Researchers have also reported that when vegetables are chopped into small pieces or liquified, more nutrients are released from the leaves [1]. A possible reason for the findings in this study is that the heat used during the cooking process released vitamin C from the broccoli plant cell walls and produced a higher concentration in smoothies made with cooked versus raw broccoli. To study and support these results and conclusions further, the same study should be repeated with other vegetables. Vegetables with different thickness plant cell walls such as spinach, kale, zucchini and cauliflower should be evaluated for vitamin C levels using the same cooking methods and technique for smoothie preparation. Additionally, this study used only the DCPIP method to measure vitamin C levels in food. Vitamin C levels in foods can be measured in a laboratory using more complex methods such as the UV/VIS spectrophotometer. Using more advanced techniques to measure vitamin C

levels in the vegetables could also advance this experiment in future studies.

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