Effect of boiling on the vitamin c biology essay

Abstract

This experiment was designed to investigate the effect of boiling on the vitamin C content of selected vegetables (bitter gourd, broccoli, cabbage, cauliflower, green pepper, sweet peas, long beans and tomato). Vegetables were boiled for 10 minutes. The juices of both raw and boiled vegetables were extracted and titrated with 1 cm3 of 0. 1% DCPIP solution. The volume of each juice needed to decolourise the DCPIP solution was measured and the vitamin C content was determined. The same procedure was repeated with other types of vegetables. The statistical t-test (paired sample) showed that the vitamin C content of raw vegetables is significantly higher than that of boiled vegetables. The results support the hypothesis; boiling reduces the vitamin C content of vegetables.

Cumulative word count: 135

Research and Rationale

Vitamin C is needed for growth, the healings of wounds, and the repair and maintenance of cartilage, bones and teeth. It is essential in the formation of collagen, a structural protein needed in the synthesis of skin, scar tissue, tendons, ligaments and blood vessels.[1]The antioxidant activity of vitamin C reduces the damage caused by free radicals, which contribute to aging, cancer, heart disease and inflammatory conditions.[2]Vitamin C improves resistance to infection and reduces the risk of cardiovascular diseases by raising the level of blood high-density lipoproteins (HDL) cholesterol.[3]4

The Recommended Dietary Allowance (RDA) of vitamin C is approximately 90mg for men and 75mg for women. 2 Vitamin C must be consumed through our diet because it is not stored in our body. Since it is water soluble, excessive amounts of vitamin C are excreted via urine. 1 Deficiency in vitamin C can lead to scurvy.[5]Sources of vitamin C include citrus fruits and fresh vegetables.[6]

Cumulative word count: 337

The main biologically active form of vitamin C is ascorbic acid. In this experiment, the presence of ascorbic acid is indicated by a redox dye, DCPIP (2, 6-dichloroindophenol).[7]DCPIP reacts with ascorbic acid in a 1: 1 ratio. Ascorbic acid, being a reducing agent, reduces the DCPIP, while ascorbic acid itself is oxidised to dehydroascorbic acid.

Ascorbic acid Dehydroascorbic acid

DCPIP (blue) Reduced DCPIP (Colourless)

Figure 1: The oxidation of ascorbic acid and reduction of DCPIP[8]

The end-point of this DCPIP titration is when the blue colour of DCPIP disappears, forming a colourless solution which persists for 10 seconds or more. 8 This method is chosen because DCPIP is less toxic. It is assumed that the vegetable tissue component which reduces the DCPIP rapidly is vitamin C.

Cumulative word count: 495

Traditionally, vegetables are cooked to destroy germs, to soften the food so that it can be easily digested, to make them look attractive and to enhance the taste.[9]1011However, the stability of vitamin C is affected by exposure to air or light, presence of metals or heat and alkalinity. Marzena et al (2007) reported that boiling caused a reduction in vitamin C content (3. 68 mg/100g in potatoes and 2. 38mg/100g in carrots)[12].

This experiment was aimed to compare the vitamin C content of raw and boiled vegetables, thus determining the best method of consuming them so that the intake of vitamin C is maximised. Vegetables selected are those which are eaten raw or after being boiled by Malaysians. Vegetables such as broccoli and green pepper were selected because of their high vitamin C content so that the loss of vitamin C during boiling is more significant.

Furthermore, the vitamin C content of cooking water of broccoli, cauliflower, cabbage and tomato were also determined to identify whether the vitamin C content was lost due to heat from boiling or leaching into the cooking water. These vegetables were chosen because they are the typical ingredients to make vegetable soup.

Some people rarely eat raw vegetables.[13]14The results from this experiment can be used as evidence that eating fresh, raw vegetables are healthier as they contain more nutritional values. Consuming boiled vegetables may result in a lower intake of vitamin C because the water used for boiling is usually discarded. Thus, it may also be advisable to use the cooking water as a soup base to prevent wastage of vitamin C.

Cumulative word count: 855

Experimental Hypothesis

The vitamin C content of the raw vegetables is significantly higher than that of boiled vegetables.

Null Hypothesis

There is no significant difference between the vitamin C content of raw and boiled vegetables.

Variables

Manipulated: State of vegetables (raw, boiled)

Responding: Volume of vegetable juice needed to decolourise 1cm3 DCPIP solution

Fixed: Type and concentration of vegetable juice, length of exposure to air after blending the juice, volume of 0. 1% DCPIP solution, standard vitamin C solution, boiling time and amount of water used for boiling.

Apparatus

Test tubes, test tube rack, 500ml volumetric flask, pipette (to measure accurately to 1cm3), burette, pestle and mortar, measuring balance, glass rod, 200ml beaker, blender, a stainless steel pot and stove.

Materials

0. 1% DCPIP solution, vitamin C tablet, distilled water, muslin cloth and eight different types of vegetables listed in Table 5.

Cumulative word count: 995

Planning

A trial experiment was conducted using cabbage to determine the most suitable method of manipulating the variable. The vitamin C was extracted by blending 100g cabbage in 100ml distilled water using a commercial blender. The juice extracted was then boiled for 10 minutes. Another 100g of cabbage was boiled in 100ml cooking water for the same period of time. The boiled cabbage was blended to extract its juice. The control experiment was carried out using raw cabbage juice.

Cabbage

Volume of cabbage juice needed to decolourise 1 cm3 DCPIP solution (ml)

Raw

9. 70

Blended, then boiled

11. 30

Boiled, then blended

15. 75

Table 1: Results for the different methods used to determine the volume of juice needed

The results show that boiling the cabbage before blending it had the most significant effect on the vitamin C content. Besides, this is the conventional way of cooking. Thus, the method of boiling before blending was used.

The ratio of cabbage to cooking water to be used was identified. 100g of cabbage was added to either 100ml (1: 1 ratio) or 200ml (1: 2 ratios) distilled water and boiled.

Cabbage

Cabbage to cooking water ratio

Volume of juice needed (ml)

Raw

–

9. 70

Boiled

1: 1

1: 2

13. 65

15. 85

Table 2: The volume of cabbage juice needed with respect to different cabbage to cooking water ratio

Based on table 2, when a ratio of 1: 1 was used, the difference in volume of juice was small. Thus, the cabbage to water ratio was changed to 1: 2 so that the effect was more significant.

Cumulative word count: 1251

The most suitable concentration of DCPIP solution to be used was determined. 0. 1g of DCPIP was dissolved in either 100ml or 10ml distilled water.

Volume of distilled water (ml)	**Concentration of DCPIP solution (%)**	**Volume of cabbage juice needed (ml)**	
		Raw	**Boiled**
100	0. 1	9. 7	15. 7
10	1. 0	34. 6	54. 0

Table 3: The volume of cabbage juices needed to decolourise 1 cm3 DCPIP solution with respect to different concentration of DCPIP solution

DCPIP solution of concentration 0. 1% was used because a smaller volume of cabbage juice is needed to decolourise the DCPIP solution. This makes the procedure easier and shortens the experimental time.

Cumulative word count: 1354

Real Experimental Procedures

I Preparing standard vitamin C solution

A vitamin C tablet was crushed into fine powder with a pestle and mortar.

62. 5mg of the vitamin C powder was weighed using a measuring balance. The powder was dissolved in a 200ml beaker by adding 10ml portions of distilled water. The solution was stirred using a glass rod.

The solution was transferred into a 500ml volumetric flask. The beaker and glass rod were rinsed with successive portions of distilled water and the washings was transferred into the flask. The solution was made up to mark using a dropper.

The solution is now exactly 0. 125 mg of ascorbic acid per cm3 of solution.

Steps 2 to 4 were repeated to prepare different concentrations of vitamin C solution listed in Table 4 using different amounts of vitamin C powder.

II Preparing standard curve of vitamin C

1cm3 of 0. 1% DCPIP solution was pipette into a test tube.

A burette was filled with 0. 125 mg cm-3 vitamin C solution.

The vitamin C solution was added drop by drop into the test tube containing DCPIP solution until the blue DCPIP decolourises. The tube was shaken gently after each drop. The volume of vitamin C solution needed was measured.

The procedure was repeated twice to get an average titre.

Steps 1 to 4 were repeated using vitamin C solution of concentrations listed in Table 4.

A standard vitamin C curve (Graph 1) was plotted based on the result.

Cumulative word count: 1608

III Identifying the vitamin C content of raw and boiled vegetables

The non-edible parts of a bitter gourd were removed.

100g of bitter gourd was blended in 100ml distilled water using a commercial blender and was filtered using a muslin cloth.

The volume of the freshly extracted vegetable juice needed to decolourise the DCPIP solution was determined using steps 1 to 4 in Experiment II.

100g of bitter guard was boiled for 10 minutes in 200ml boiling water using a 5-inch-deep stainless steel pot.

After 10 minutes, the boiled bitter gourd was immediately removed from the cooking water and cooled by immersing in an ice-cold water bath for 5 minutes.

Steps 2 and 3 were repeated using the boiled vegetables.

This experiment was repeated with the other vegetables listed in Table 5.

The vitamin C content of all vegetables was calculated using the standard vitamin C curve.

The data of volume needed and vitamin C content were tabulated.

A graph of vitamin C content of raw and boiled vegetables was plotted.

A t-test was used to statistically analyse the data.

IV Identifying how vitamin C is loss

The cooking water of broccoli, cabbage, cauliflower and tomato was collected.

200ml distilled water was added to the cooking water. It was cooled by immersing in an ice-cold water bath for 5 minutes.

Steps 1 to 4 in Experiment II and steps 8 and 9 in Experiment III were repeated using the cooking water.

The difference between vitamin C content of vegetables before and after boiling (inclusive of its cooking water) was calculated.

A graph of vitamin C content of cooking water was plotted.

Cumulative word count: 1895

Safety Precautions

Heat resistant gloves were worn when dealing with boiled vegetables.

Laboratory coat and goggles were worn to prevent the DCPIP solution and vitamin C solution or vegetable juices from staining the clothes or skin, or getting into the eyes.

All glasswares such as test tubes, pipette and beakers were handled with extra care since the apparatus could break easily and cause injury.

When using the burette, care must be taken to ensure that no air bubbles were trapped at the jet which may affect the accuracy of the titre.

Cumulative word count: 1990

Results

I Preparing standard vitamin C solution

Mass of vitamin C powder (mg)

Concentration of Vitamin C solution (mg cm-3)

Volume of vitamin C solution (ml)

1

2

3

Average

62. 5

0. 125

10. 30

10. 20

10. 20

10. 20

125. 0

0. 250

5. 20

5. 20

5. 15

5. 20

187. 5

0. 375

4. 00

4. 05

4. 00

4. 00

250. 0

0. 500

2. 90

3. 00

3. 00

3. 00

312. 5

0. 625

1. 80

1. 80

1. 80

1. 80

375. 0

0. 750

1. 40

1. 35

1. 50

1. 40

Table 4: The mass of vitamin C powder needed for serial dilution and the volume of vitamin C solution needed to decolourise 1 cm3 DCPIP solution

Cumulative word count: 2082

II Standard Vitamin C curve

Cumulative word count: 2133Graph 1: Graph of volume of vitamin C solution needed to decolourise 1 cm3 of 0. 1% DCPIP solution against concentration of Vitamin C

III Calculating the vitamin C content of raw and boiled vegetables

From graph 1, vitamin C solution is needed to decolourise 1 cm3 0. 1% DCPIP solution.

Using the formula:

where

v = Volume of vitamin C solution needed to decolourise the DCPIP solution

c = concentration of vitamin C solution

k = constant

It can be derived that:

Thus, the vitamin C content of vegetables, c can be calculated by:

Cumulative word count: 2219

Types of vegetables

Volume needed to decolourise 1cm3 0. 1% DCPIP solution (ml)

Raw vegetables

Boiled Vegetables

1

2

3

Average

1

2

3

Average

Bitter gourd

2. 40

2. 55

2. 45

2. 50

4. 20

4. 05

4. 10

4. 10

Broccoli

4. 25

4. 20

4. 15

4. 20

6. 20

6. 15

6. 20

6. 20

Cabbage

9. 70

9. 55

9. 60

9. 60

15. 60

15. 80

15. 75

15. 70

Cauliflower

2. 85

2. 85

2. 65

2. 80

3. 65

3. 65

3. 75

3. 70

Green pepper

1. 20

1. 05

1. 30

1. 20

3. 50

3. 40

3. 60

3. 50

Sweet peas

4. 25

4. 40

4. 25

4. 30

9. 00

9. 00

8. 80

8. 90

Long beans

13. 00

13. 00

12. 90

13. 00

21. 00

21. 20

20. 90

21. 00

Tomato

0. 55

0. 70

0. 60

0. 60

1. 85

2. 00

1. 90

1. 90

Table 5: Volume of juices needed for different types of raw and boiled vegetables

Types of vegetables

Vitamin C content (mg cm-3)

Raw vegetables

Boiled Vegetables

Bitter gourd

Broccoli

Cabbage

Cauliflower

Green pepper

Sweet peas

Long beans

Tomato

Cumulative word count: 2387Table 6: Vitamin C content of raw and boiled vegetables

Cumulative word count: 2430Figure 2: Bar chart of vitamin C content of raw and boiled vegetables

IV Identifying how vitamin C is loss

Cooking water

Volume needed to decolourise 1cm3 0. 1% DCPIP solution (ml)

Vitamin C content (mg cm-3)

1

2

3

Average

Broccoli

13. 20

13. 00

13. 15

13. 10

Cabbage

15. 20

15. 20

15. 00

15. 10

Cauliflower

15. 70

15. 85

15. 80

15. 80

Tomato

9. 45

9. 50

9. 50

9. 50

Table 7: The vitamin C content of cooking water

Types of Vegetables

Vitamin C content (mg cm-3)

Before boiling

After boiling

Difference

= Before – After (Raw – Total)

Raw

Boiled

Cooking water

Total

(Boiled + Cooking water)

Broccoli

0. 4277

-0. 0009

Cabbage

0. 2335

0. 0460

Cauliflower

0. 6004

-0. 0425

Tomato

1. 1369

-1. 8631

Cumulative word count: 2553Table 8: Difference in total vitamin C content before and after boiling

Cumulative word count: 2598Figure 3: Bar chart of vitamin C content of cooking water

Statistical Analysis

The paired sample t-test was used to analyse the data.

Types of vegetables

Vitamin C content (mg cm-3)

Difference, d = Raw – Boiled

Raw

Boiled

Bitter gourd

0. 7200

0. 4390

0. 2810

Broccoli

0. 4286

0. 2903

0. 1383

Cabbage

0. 1875

0. 1146

0. 0729

Cauliflower

0. 6429

0. 4865

0. 1564

Green pepper

1. 5000

0. 5143

0. 9857

Sweet peas

0. 4186

0. 2022

0. 2164

Long beans

0. 1385

0. 0857

0. 0528

Tomato

3. 0000

0. 9474

2. 0526

Table 7: Difference in vitamin C content of raw and boiled vegetables

Cumulative word count: 2735The calculated t-value (2. 005) shows it is significant whereby it exceeds the tabulated t-value, which is 1. 895 ($p < 0.05$, d. f.= 14). Thus, the experimental hypothesis is accepted and the null hypothesis is rejected. The vitamin C content of the raw vegetables is significantly higher than that of boiled vegetables.

Data Analysis

The vitamin C content of raw vegetables is on average 0. 4945 mg cm-3 higher than that of boiled vegetables. The percentage loss of vitamin C during boiling is 56. 22%. Error bars displayed on Figure 2 represent the overall distribution of the data. Upper error bar for boiled vegetables does not overlap the range of value within error bar of raw vegetables. Thus, these two vitamin C content values differ significantly.

Figure 2 shows that raw vegetables have higher vitamin C content than boiled vegetables, suggesting that it is best to eat raw vegetables rather than those boiled. Nevertheless, if vegetables were to be boiled, it is advisable to serve the vegetables with the cooking water since vitamin C is found in the cooking water after boiling (Figure 3).

Cumulative word count: 2865

Boiling breaks down the cell wall of vegetables, causing their permeability to increase. Vitamin C, being water-soluble, leaches into the cooking water. This agrees with the data in Table 7 as vitamin C is found in the cooking water after boiling. The vitamin C is lost as the cooking water is discarded. [15]

The reduction in vitamin C content of vegetables (including their cooking water) after boiling as shown in Table 8 agrees with the suggestion that vitamin C is lost due to thermal degradation.[16]17The high temperature of boiling water increases the rate of oxidation of L-ascorbic acid to L-dehydroascorbic acid. L-dehydroascorbic acid, being unstable, tends to undergo hydrolysis to form diketogulonic acid, a physiologically inactive compound. This suggests that heat produced during boiling can cause vitamin loss.

Figure 4: The destruction of vitamin C[18]

Burg & Fraile (1995) reported that vitamin C can also be destroyed by enzymatic destruction and enzyme thermal deactivation reactions during home cooking.[19]20

Cumulative word count: 3123

However, the results differ for cabbage. Unlike the other three vegetables, the total vitamin C content of cabbage after boiling is 0. 0460 mg cm-3 higher than that of raw cabbage. This may be due to the more complete extraction of juice as the cabbage tissue is softer after boiling.

The results of my investigation are supported by a previous investigation by Podsedek A. et al (2007) on two varieties of red cabbage – Koda and Kissendrup. The vitamin C content of vegetables decreased after boiling.[21]

Cooking method

Cooking time (min)

Vegetable: water (g/ml)

Koda

Kissendrup

Vitamin C content (mg/100g)

Raw cabbage

72. 56

62. 00

In boiling water

20

1: 2

23. 74

26. 77

20

1: 1

33. 61

38. 36

10

1: 1

31. 74

38. 72

Table 8: The effect of boiling on the vitamin C content of red cabbage

Moreover, Carol Reiss (1993) reported an average of 21. 75mg/100g ascorbic acid in the cooking water after boiling a cabbage. This agrees with my results that vitamin C is present in the cooking water after boiling.[22]

Cumulative word count: 3360

Evaluation

The tube was shaken gently and consistently during each experiment after each drop of vitamin C solution to allow rapid diffusion of vitamin C throughout the DCPIP solution. Shaking the tube too vigorously may cause oxygen from air to dissolve and oxidise the reduced DCPIP solution, restoring the blue colour. Then, an increased volume of vegetable juice may be needed. All vegetable juices, as well as those boiled, should be titrated with the DCPIP solution once they have been extracted because vitamin C is easily destroyed by the atmospheric oxygen via oxidation. The DCPIP solution must be freshly prepared on the day of experiment. The DCPIP solution was filtered to avoid any impurities suspending at the bottom of test tube. Similarly, the vegetable juice was filtered to remove the vegetable pulp which may clog the burette tap.

The non-edible parts and damaged leaf or stem of the vegetable samples were removed. Vegetables were cut into small cubes of about the same size so that the surface area exposed to the cooking water is constant. They were added into the pot only after the water starts boiling to keep the boiling temperature and duration constant. A stainless steel pot was used as ordinary pots may have transition metals which may oxidise the ascorbic acid.

Before starting the experiment, a rough titration was run to determine the exact colour change at the end point. For cauliflower, the colour may change from blue to pale yellow, which is the colour of the cauliflower juice. [Appendix]

To minimise inaccuracy, the procedure was repeated to get an average titre. Eight types of vegetables were sampled to obtain enough replicates to support the hypothesis. A burette and pipette were used because of their high accuracy. Burette readings are accurate to 0. 05cm3. Since two readings are taken, there is a combined error of ± 0. 1cm3. If the titre is 20. 00cm3, the possible error due to apparatus is 0. 5%.

Cumulative word count: 3682

Limitations in this experiment include the ripeness, place of origin, storage and handling conditions of the vegetables.[23]The season of year and time of day from which the vegetables were picked were uncontrollable. They were bought from a hypermarket and were chosen based on their appearance such as colour and degree of damage.

Modifications include repeating the experiment using other types of vegetables such as potatoes and carrots. Boiling may have different effects on different varieties of vegetables as their nutritional contents vary. Using only eight types of vegetables may give a wrong representation on the effect of boiling on the vitamin C content of all vegetables.

The experiment can also be modified to investigate the effect of other cooking methods like deep-frying, steaming and microwave cooking on the vitamin C content of vegetables thus determining the best cooking method which results in minimal vitamin C loss.

To ensure complete extraction of ascorbic acid, the vegetables can be blended with 5% metaphosphoric acid. This acid inactivates the enzyme ascorbic acid oxidase (an enzyme present in many plant tissue) which catalyses the oxidation of ascorbic acid when the cell components of a vegetable is mixed during blending.[24]25

Conclusion

Boiling significantly reduces the vitamin C content of vegetables (by 56. 22%). The vitamin C content of raw vegetable is significantly higher than that of boiled vegetable.

Cumulative word count: 3947

Source Evaluation

Source 4 is a published book with ten contributors. Hence, the information provided is reliable and factual unless it has become out-dated since it was published in 1993.

Source 5 (The Star) is Malaysia's most widely-read English-language daily. One of its pullouts, Fit for Life, provides up-to-date articles on diet and nutrition. Therefore, the information can be trusted.

ScienceDirect (Source 10) offers more than 2, 500 peer-reviewed journals and more than nine million full-text articles. EBSCO (Source 11) provides online information databases and has a renewal rate of 99. 6%. Thus, these online-journal sources are trustable.

Source 12 is a website produced by the National Library of Medicine, a part of the National Institutes of Health. It shares extensive information on over 800 diseases and health conditions, and is reviewed at least every 6 months. Thus, it should be reliable.

Cumulative word count: 4087

Appendix

Figure 2: The colour change at end point for cauliflower

Cumulative word count: 4098