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VITAMIN C CONTENT AND ANTIOXIDANT ACTIVITY OF EIGHT SELECTED VEGETABLES WIDELY CONSUMED IN ADDIS ABABA, ETHIOPIA

Abdelah Abajihad and Bhagwan Singh Chandravanshi*

Department of Chemistry, College of Natural and Computational Sciences, Addis Ababa University, P. O. Box 1176, Addis Ababa, Ethiopia

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ABSTRACT. The objectives of the study were to determine vitamin C content using iodometric titration and its antioxidant activity as a DPPH assay by UV−Vis spectrophotometric method in eight shade-dried vegetables purchased from Addis Ababa in open markets. The linear range of standard vitamin C was in the range 3.2–52 mg/L with a correlation coefficient of $R^2 = 0.994$. The vitamin C content was found in the increasing order in eggplant 6.83 mg/100 g < carrot 11.05 mg/100 g < beetroot 15.32 mg/100 g < Swisschard 16.22 mg/100 g < cauliflower 17 mg/100 g < lettuce 21 mg/100 g < cabbage 32.49 mg/100 g < green chili 49.18 mg/100 g. The percentage recoveries of vitamin C in the vegetables ranged from 95.61 to 102.4%, indicating its good reliability. The antioxidant activity of eight vegetables was increasing, namely in eggplant 12.48 mg/100 g < carrot 30.55 mg/100 g < beetroot 30.55 mg/100 g < cauliflower 42.98 mg/100 g < Swisschard 44.57 mg/100 g < lettuce 63.48 mg/100 g < cabbage 100.9 mg/100 g < green chili 106.8 mg/100 g. The results also revealed a strong correlation ($R^2 = 0.9508$) between vitamin C contents in the vegetables and their antioxidant activities.

KEY WORDS: Vegetable, Vitamin C, Iodometric titration, DPPH antioxidant, UV−Vis spectrophotometry

INTRODUCTION

Plants are a natural source of several ingredients that are used to treat a wide range of illnesses and promote health and lower the risk of disease [1]. Vegetables are any plant or any of its parts (leaves, roots, shoots, flowers, seeds, and fruits) that are consumed raw or cooked with food and are frequently salted or added to salads and desserts. Due to their ability to provide phytochemicals, vitamins and minerals including iron, calcium, magnesium, zinc and other vital components for human health, vegetables are a crucial part of any meal [2, 3].

Vitamins C and the B complex are water-soluble chemical molecules, whereas vitamins A, D, E, and K are categorized as fat-soluble organic molecules. Vitamin C with the molecular formula $C_6H_8O_6$ is also known as L-ascorbic acid. The human body is unable to synthesize vitamin C. Therefore, eating fruits and vegetables is the best way to obtain it [4-6]. It is an extremely important antioxidant for human nutrition and the body's healthy operation [7]. Vitamin C is necessary for the development and maintenance of skin, blood vessels, and bones in humans. It is necessary for the synthesis of L-carnitine, collagen fibers, and some neurotransmitters. It is also involved in protein metabolism [8].

Antioxidants protect the body from adverse biological reactions involving oxygen or preventing the oxidation of other chemicals [9]. These act as scavengers for free radicals and reactive oxygen species, thereby preventing them from disrupting the chemical stability of the cells [10]. Fortunately, the body has a natural defense system against cellular damage by free radicals, which comprise primarily of antioxidant nutrients (e.g., vitamin E, vitamin C and certain carotenoids), which are assisted by a variety of phytochemicals from the diet [11].

*Corresponding authors. E-mail: bscv2006@yahoo.com

Many analytical methods are used for determination of vitamin C contents, such as titrimetric and iodometric [12]. The 2,6-dichloroindophenol method [13], voltammetric method [14], spectrophotometric method [15], and high performance liquid chromatographic methods [4, 16].

Ethiopia is a country with different climatic conditions and agricultural practices. However, there is a limited information on the vitamin C content of locally grown vegetables. This lack of information hinders the ability to fully understand and utilize the nutritional potential of these vegetables for promoting health. Therefore, it is necessary to determine vitamin C (L-ascorbic acid) content in selected vegetables including beetroot (*Beta vulgaris* L.), cabbage (*Brassica oleracea var. capitate*), carrot (*Daucus carota* L.), cauliflower (*Brassica oleracea* L. var. botrytis), eggplant (*Solanum melon Gena* L.), green chili (*Capsicum anuum* L.), lettuce (*Lactuca sativa* L.), and Swiss chard (*Beta vulgaris*), which are commonly produced and consumed in Ethiopia. The characteristic features of these vegetables are briefly reviewed.

Beetroot (*Beta vulgaris* L.) is a member of the Chenopodiaceous family. Beetroot is a rich source of nutrients. It contents iron, magnesium, selenium, potassium, calcium, zinc, phosphorus, and sodium [17]. The bioactive compounds include phenolic compounds, saponins, and especially battalias, which are responsible for the characteristic color of this tuber. Other components are bioflavonoid, pure sugar and betain. Beetroot has antiviral and antimicrobial effects and antioxidant and anti-inflammatory properties [18]. Consumption of beetroot reduces inflammation, an innate response including inflection, erythema, edema, trauma, fever, and pain that are caused due to cell damage by antigens.

Cabbage (*Brassica oleracea* var. capitate L.) is a biennial herb with a short, thickened stem surrounded by a series of overlapping leaves that form a compact head. The head may be pointed or round. The major cabbage-producing countries are China, India, the Russian Federation, Japan, and the Republic of Korea [19]. Cabbage is one of the most popular vegetable crops grown worldwide [20]. Cabbage is known as a source of vitamin C, minerals, and dietary fiber. Cabbage also contains substances that help the liver metabolize toxins: vegetal albumin, gum, gum extract, potassium nitrate, oxides of Fe, S, proteins, lipids, carbohydrates, and vitamins. Substances that help the liver metabolize toxins, vegetal albumin, supporting digestion and heart health, antioxidant effects, immune system support, lowering the risk of some health issues, and potentially helping prevent cancer.

Carrot (*Daucus carota* L.) is one of the popular root vegetables grown throughout the world and is the most important source of dietary carotenoids in Western countries, including the USA. China produces about one-third of all carrots bought and sold worldwide. It is the best source of carotene and a precursor of vitamin A. Carrots contain vitamins such as vitamin C and K, thiamine (B_1), riboflavin (B_2), pyridoxine (B_6) and folates (B_9), necessary for metabolism of carbohydrates, proteins and healthy growth. Carrot juice is naturally, high in antioxidant activity of polyphenols even after processing [21]. Carrots are known for their rich supply of the antioxidant nutrient that was actually named for them: beta-carotene. Carrot also contains abundant quantities of nutrients and minerals [10, 11].

Cauliflower (*Brassica oleracea* L. convarbotrytis L.) is high in nutritional value with its minerals, carotene, and vitamins [22]. Cauliflower is easily digestible and has a high Ca content, which is good for building bones and providing needed vitamin C, minerals and many essential B complexes [23]. It contains diindolyl methane (DIM) lipid-soluble phytochemical in the brassica group of vegetables in large amounts [24]. It plays a role in the prevention of the development of genetically determined cancers and stimulates the natural antioxidant system with its glucosinolates and isothiocyanates (ITCs). It is excellent source of vitamin C, good source of fiber, source of vitamin K, folate low in calories, fat, and cholesterol.

Eggplant (*Solanum melongena* L.) is a non woody annual plant with purple to white flowers along with enlarged lobed leaves with bushy foliage that grows with maximum height of 120 cm. It is a financially important crop grown in many countries throughout the subtropics, tropics, and Mediterranean area and their cultivars produce wide fruit diversity with different shapes, sizes, and colors [25-27]. Eggplants have an important nutritional value due to their composition, which includes minerals, host of various vitamins, phenol, calcium, potassium, magnesium, sodium, and iron as well as dietary fiber. Its antioxidant property potentially reduces the risk of various types of cancer, protects against cardiovascular diseases and prevents acute respiratory infections [28, 29]. Further, eggplant fibers help digestion by removing toxins and harmful materials from the stomach and reducing colon cancer [30].

Chilli pepper, or hot pepper (*Capsicum annuum* L.) is an important spice and vegetable crop of the family Solanaceae. They contain carbohydrate, protein, Na, fat, Ca, vitamin A, vitamin C 250-300 mg, potassium 340 mg, vitamin B_6, Fe, P, Cu, and fiber [31]. Green chili has a good amount of antioxidants and different types of vitamins. These components protect from free radicals (unstable atoms that damage cells) and lead to chronic illness. For this reason, green chili can protect against diseases like stroke, cancer, diabetes, and arthritis. Also improves eye sight, enhances digestion, and supports maintaining weight and heart patients [32].

Phytochemicals content of lettuce (*Lactuca sativa* L.) can be differentiated for individual varieties; therefore, it is essential to choose those that are characterized by a high level of phytochemicals [33]. The chemical composition (mineral contents, phytate, oxalate, etc.) of lettuce are reported in the literature [34]. Lettuce also provides some vitamin C, calcium, iron, and copper, with vitamins and minerals largely found in the leaf [34].

Swiss chard (*Beta vulgaris* ssp. cicla L.) is a dark green leafy vegetable available throughout the year [35]. Swiss chard is a very good source of vitamins C, A, and B, phenolic acids (syringic, caffeic, and *p*-coumaric), flavonoids (kaempferol, quercetin, and glycosides derived from apigenin), and minerals such as iron, potassium, calcium, magnesium, and manganese, which additionally contribute to the functionality of Swiss chard [36]. Swiss chard also contains a good amount of dietary fibers and proteins, which also enhances its role in blood sugar regulation [35]. Additionally, due to the low energy values as well as the low fat content Swiss chard could be recommended for controlling cholesterol, prevention of obesity, weight reduction, bone health, blood clothing, healing, and vision.

The objectives of the present study were to determine the content of vitamin C in the eight selected shade dried vegetables using iodometric titration and their antioxidant activity as DPPH assay by UV-Vis spectrophotometric method and to compare the content of vitamin C and their antioxidant activity among the eight selected vegetables.

EXPERIMENTAL

Apparatus and instrument

Grinder (mortar and pestle), double beam spectrophotometer (Lambda 950 – UV-Vis-NIR, Perkin Elmer, UK) interfaced with a computer using 2 nm resolution in a 1 cm path length quartz cell, electronic balance (model: ARA520, China), water de-ionizer system (model: Molatom520d, Molwater system Co, Ltd), centrifuge (model 80-2, China) and Whitman filter paper No. 41 were used.

Chemicals

All the reagents and chemicals used were analytical-grade reagents. KIO_3, KI, starch indicator, and 96% H_2SO_4 (Carlo Erba, Italy) along with L-ascorbic acid (Riede-de Haen, Germany), DPPH (2,2-diphenyl-1-picrylhydrazyl, Sigma Aldrich, USA), and 99.8% methanol (Himedia, India) were used. Deionized water was used throughout the experiment.

Vegetable collection

For this study, the fresh vegetables were collected. The eight vegetables, namely beetroot, cabbage, carrot, cauliflower, eggplant, greenchili, lettuce and Swiss chard, were purchased from Addis Ababa city's open markets (Arat Kilo) and transported to the analytical chemistry laboratory, Addis Ababa University. 1 kg of each of beetroot, carrot, eggplant, green chili; 3 kiosks of lettuce and Swiss chard; and two pices of cauliflower and cabbage were bought in November 2022. Table 1 summarizes English names, scientific names, local names and parts of vegetable samples analyzed in this study.

Table 1. English name, scientific name, local name and parts of vegetable samples analyzed.

No.	English name	Scientific name	Ethiopian name	Analyzed parts
1	Beetroot	*Beta vulgaris* L. var. rapacea Koch	*'Kaiser'*	Root
2	Cabbage	*Brassic oleracea* var. capitata	*'Tikil goman'*	Leaves
3	Carrot	*Daucus carota* ssp. sativus	*'Carrot'*	Root
4	Cauliflower	*Brassica oleracea* L.	*'Ababa goman'*	Flower
5	Eggplant	*Solanum melongena* L.	*'Dabarjan'*	Fruit
6	Green chilli	*Cucumis sativus* L.	*'Karya'*	Fruit
7	Lettuce	*Lactuca sativa*	*'Salata'*	Leaves
8	Swiss chard	*Beta vulgaris* L. var. cicla	*'Costa'*	Leaves

Basic principle of vitamin C determination

Vitamin C content was determined by iodometric titration. In this titration, KIO_3 is added to a solution of vitamin C, which contains strong acid (H_2SO_4) and KI. The chemical reactions involved in the titration are given by Equations 1–3. The potassium iodate reacts with potassium iodide, which librates iodine:

$$KIO_3 + 5KI + 6H \rightarrow 3I_2 + 6K + 3H_2O \quad (1)$$

Iodine is relatively insoluble, but this can be improved by complexing the iodine with iodide to form tri-iodide:

$$I_2 + I^- \rightleftharpoons I_3^- \quad (2)$$

Tri-iodide oxidizes ascorbic acid to form dehydroascorbic acid:

$$C_6H_8O_6 + I_3^- \rightarrow C_6H_6O_6 + 3I^- + 2H^+ \quad (3)$$

The potassium iodide is always added in excess to ensure completion of the reaction and to dissolve the iodine.

Method of vitamin C sample extraction

Vitamin C in the eight selected vegetable samples were extracted according to the reported method [37] with some modifications. Briefly, vegetables were chopped using a knife and allowed for shade drying for fourteen consecutive days. The dried sample parts were ground using mortar and pestles to get their fine powder. Then, a 250 µm sieve was used to screen thoroughly and get a uniform texture. 1 g of each of the sample powders were accurately weighed and added to 100 mL deionized water using a 100 mL volumetric flask. The mixture was mechanically shaken with hands for 15 min. The mixture was transferred into clean, dried centrifuge tubes and centrifuged at 3500 rpm for 15 min at room temperature. The solution was filtered through Whatman filter paper no. 41 and stored in air tight tubes in the dark place.

Preparation of solutions

Procedures for the preparation of solutions have been described elsewhere [37].

Determination of vitamin C

The method for the determination of ascorbic acid by iodometric titration was adopted from Belete *et al.* [37] with some modifications. It is based on iodometric titration of the sample with a standardized iodine solution. To determine the amount of vitamin C in eight selected vegetables, 20 mL of the aqueous extract of the vegetables were taken, and 1.5 mL of 0.5% starch solution were added into a 125 an Erlenmeyer flask, and these solutions were titrated immediately against the prepared iodine solution (0.007028 M) with continuous shaking, and the end point was recorded for all vegetables. All the determinations were carried out in triplicate titration. The result was expressed in mg of vitamin C per 100 g of vegetables.

Determination of antioxidant activity of vegetables by DPPH assay

Eight vegetables were analyzed for their antioxidant activity. The antioxidant activities of the selected vegetables were determined using the DPPH assay method [37]. Briefly, 1 mL of each of the samples extracted was mixed with 4 mL of methanol and 2 mL of 200 mg/L DPPH solution in flasks, and the mixture was allowed to react at room temperature in the dark for one hour. The color turns purple to yellow as the DPPH radical reduces when the odd electron of DPPH is paired with hydrogen from a free radical scavenging antioxidant to form where the reduced DPPH-H. The resulting decolorization is related to the number of electrons captured. The control was measured by using the mixture of 4 mL methanol and 2 mL DPPH solution. The absorbance of the reaction mixtures was measured at 517 nm. Each sample was analyzed in triplicate, and the mean was taken. The antioxidant activity of the sample is expressed in mg vitamin C per 100 g.

RESULTS AND DISCUSSION

Statistical analysis of data

All measurements were done in triplicate and results were presented as mean ± standard deviation (SD) (n = 3). Statistical treatment of data were conducted using (Microsoft Excel).

Standardization of the iodine solution

A 3.69 x 10^{-4} M solution of vitamin C was titrated against the 0.007028 M iodine solution. The end point of titration was a dark blue-black color due to the starch-iodine complex. Titration was conducted in triplicate, and then the mean was taken for reliability of the result (Table 2).

Table 2. The iodine standardized with vitamin C standard.

Mass of vitamin C (g)	Standard vitamin C (20 mL)	Initial volume of iodine solution (mL)	Final volume of iodine solution used (mL)	Volume of iodine solution used (mL)
0.0065	20	0	1	1
0.0065	20	1	2.1	1.1
0.0065	20	2.1	3.15	1.05

Vitamin C contents in the vegetables

The content of vitamin C in the vegetables was increasing in the order: eggplant 6.38 mg/100 g < carrot 11.05 mg/100 g < beetroot 15.32 mg/100 g < Swiss chard 16.22 mg/100 g < cauliflower 17 mg/100 g < lettuce 21 mg/100 g < cabbage 32.49 mg/100 g and green chili 49.18 mg/100 g (Table 3). The lowest content of vitamin C was obtained in eggplant (3.866 mg/100 g), and the highest content was found in green chili (49.18 mg/100 g). To determine the precision of the data, triplicate analysis was conducted, and then the standard deviation (SD) of the data were calculated. A relative standard deviation below 1% is a corrected result/highly accurate, and 1-5% is moderately accurate/best precision. Also below 10% is good precision.

Table 3. Vitamin C content in the vegetables determined by iodometric titration in mg/100 g.

No	Sample	Trial 1	Trail 2	Trail 3	Mean ± SD
1	Beetroot	16.245	14.622	15.272	15.37 ± 0.444
2	Cabbage	32.491	31.844	32.491	32.27 ± 0.093
3	Carrot	11.40	10.72	11.05	11.06 ± 0.081
4	Cauliflower	17.85	17.21	16.77	17.08 ± 0.458
5	Eggplant	6.498	7.486	6.5531	6.83 ± 0.771
6	Green chili	48.74	49.55	49.25	49.18 ± 0.110
7	Lettuce	22.96	21.12	21.77	21.99 ± 0.578
8	Swiss chard	15.60	16.90	16.24	16.24 ± 0.281

Recovery test

Recovery of the iodometric titration method for the determination of vitamin C was carried out by applying the standard addition technique (spike method). A different amount of standard solution was added to the same known concentrations of vitamin C (20 mL) of the sample. In this study, the recovery for the iodometric titration method in determining vitamin C in the vegetables was in the range 95–102% (Table 4), which indicates the method is accurate and reliable [38].

Table 4. Recovery percent of vitamin C for spiked samples.

No	Sample	Recovery % in mg/100 g			Mean ± SD
		Trial 1	Trial 2	Trial 3	
1	Beetroot	100.0	98.63	98.68	99.1 ± 0.40
2	Cabbage	95.99	96.85	94.44	95.76 ± 0.99
3	Carrot	96.46	96.22	98.18	96.95 ± 0.75
4	Cauliflower	100.0	101.16	101.7	100.9 ± 0.8
5	Eggplant	101.6	101.1	100.0	100.9 ± 0.43
6	Green chilli	102.46	100.0	102.03	101.5 ± 0.46
7	Lettuce	95.61	96.19	94.44	95.43 ± 0.52
8	Swiss chard	100.0	98.8	98.76	99.18 ± 0.40

Antioxidant activity of vegetables by DPPH assay

The standard calibration curve is presented in Figure 1. The quantitative determination of the antioxidant activities was carried out based on the linear correlation between absorbance (1.765, 1.713, 1.547, 1.222, 0.456) and concentration of vitamin C (3.125, 6.25, 12.5, 25.0, 52) in DPPH solution with $R^2 = 0.999$. This indicates excellent linearity of the result. It should be noted that as the concentration of vitamin C increases the absorbance decreases, in the same way concentration of the DPPH solution decreased, since it was converted to DPPH-H by taking one hydrogen atom from vitamin C.

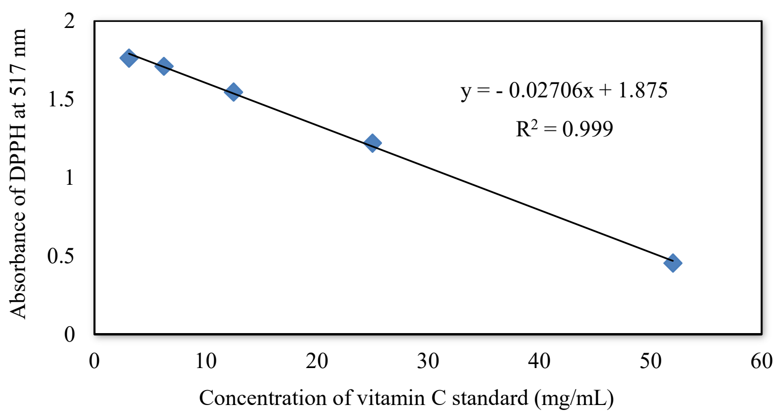

Figure 1. Calibration curve of vitamin C.

Results of antioxidant activity for the vegetables using DPPH assay by UV-Vis spectrophotometry are given in Table 5. The absorbance was measured by scanning from 650 to 400 nm, and then the absorbance was recorded at 517 nm. Each sample was analyzed in triplicate and the mean was taken.

Based on the calibration curve, the antioxidant activity of each sample was calculated using the equation of regression line: $y = -0.02706x + 1.875$ (where y = absorbance and x = concentration. The absorbance is reciprocal to the antioxidant activity of vegetables. The antioxidant activity of each sample was expressed as vitamin C equivalent mg/100 g (Table 5).

Table 5. Antioxidant activity of vegetables using DPPH assay by UV-Vis spectrophotometry.

No.	Vegetables	Concentration (mg/100 g)			Mean±SD (mg vitamin C equivalent/100 g)
		Trial 1	Trial 2	Trial 3	
1	Beetroot	36.34	36.98	36.73	36.68 ± 0.07
2	Cabbage	99.80	101.48	101.55	101.55 ± 0.65
3	Carrot	29.81	31.63	30.22	30.55 ± 0.61
4	Cauliflower	42.48	43.36	43.11	42.98 ± 0.83
5	Eggplant	12.41	12.42	12.63	12.48 ± 0.02
6	Green chili	106.0	107.4	106.9	106.77 ± 0.04
7	Lettuce	63.76	63.17	63.48	63.47 ± 0.068
8	Swiss chard	44.00	44.56	45.15	44.57 ± 0.56

The antioxidant activity (as vitamin C equivalent mg/100 g) of eight vegetables was increasing, namely in eggplant 12.48 mg vitamin C equivalent/100 g < carrot 30.55 mg vitamin C equivalent/100 g < beetroot 30.55 mg vitamin C equivalent/100 g < cauliflower 42.98 mg vitamin C equivalent/100 g < Swiss chard 44.57 mg vitamin C equivalent/100 g < lettuce 63.48 mg vitamin C equivalent/100 g < cabbage 100.9 mg vitamin C equivalent/100 g and green chili 106.8 mg vitamin C equivalent/100 g. The lowest antioxidant activity was obtained in eggplant (12.48 mg vitamin C equivalent/100 g), and the highest content was in green chili (106.9 mg vitamin C equivalent/100 g). To calculate the precision of the data on vitamin C and antioxidant activity commonly consumed vegetables, triplicate analysis was done, and then the SD and relative standard deviation (RSD) of the data were calculated. In this study, the RSD of only three samples carrots (1.986%), Swiss chard (1.301%), and cauliflowers (1.935%) were above 1%, which show good precision of the results.

Comparison of vitamin C contents in the vegetable with literature data

Comparison of vitamin C contents in the vegetables of the present study is given in Table 6. The vitamin C content in the studied vegetables ranges from 6.838 mg/100 g to 49.18 mg/100 g of dried vegetables. For eggplant, the vitamin C content in the present study is 6.838 mg/100 g, which is less as compared to the previous literature (10.9 mg/100 g) reported by Tincheva [39]. From the result obtained, drying vegetables clearly reduces the ascorbic acid content. The vitamin C content of eggplant varied (3.9 mg/100 g to 4.1 mg/100 g) and (4.8 mg/100 g to 4.9 mg/100 g) less than the present study. These differences are dependent on subspecies and not the color of the fruit reported by Shabetya *et al.* [40]. The result of present study is comparable with the vitamin C of eggplant cultivars (7.4 mg/100 g to 22 mg/100 g) reported by Niño-Medina *et al.* [41]. Present study of vitamin C in carrots is 11.058 mg/100 g. The result is similar to the previous study reported by Tinchela [39] 12.2 ± 0.5 mg/100 g. The previous literature reported vitamin C in fresh carrot 28.93 ± 0.05 mg/100 g and freshly cooked for 15 min decreased to 13.61 mg/100 g. While storages for four days resulted vitamin C to 0 mg/100 g as reported by El Sharaa and Mussa [48]. The finding is similar with freshly cooked vegetable. The shade dried Swiss chard was 16.244 ± 0.281 mg/100 g; this is in close agreement with the previous study of raw Swiss chard, which was 18.41 ± 0.34 mg/100 g as reported by Kasa [43]. In previous cases, fertilization and irrigation were involved during the study. Miceli and Miceli [44] reported that vitamin C can be increased by fertilization.

The vitamin C in cauliflower in the present study is 17 mg/100 g is higher than reported by El Sharaa and Mussa [42] (10.052 mg/100 g). The previous literature for vitamin C in cauliflower was based on storages for four days. But the present finding is shed dried for 14 days. The present study for vitamin C in lettuce is 21 mg/100 g which is comparable with 20 mg/100 g reported by Bhosale and Arya [45]. The slight difference in vitamin C content was induced by lettuce genotype [46]. According to previous reports by Aćamović-Djoković *et al.* [47], vitamin C in lettuce depends on different types of varieties of lettuce (Plenty butterhead, Murai, and Levistro) which are 3.85, 3.5, and 9.6 mg/100 g, respectively

The present determination of vitamin C in the beetroot is 15.1 mg/100 g. This result is in agreement with that beetroot organically grown as reported by Szopinska and Gaweda [48] which contains 10.05 to 11.65 mg/100 g of vitamin C. The lower vitamin C found in beetroot that varied depending on year and method of cultivation from 5.06 mg/100 g to 9.46 mg/100 g was reported by Szopinska and Gaweda [48]. In the present study, vitamin C in the cabbage is found to be 32.49 mg/100 g. The previous literature reported that vitamin C in freshly chopped cabbage (64.25 mg/100 g) and freshly cooked for 15 min decreased to 47.17 mg/100 g, and storage for four days was 0 mg/100 g [42]. The present finding is based on shed drying for 14 days. The result is not in agreement with the literature value because the effect of time and mode of drying is different. Beetroot belongs to the groups of vegetables with high antioxidant potential [49], so it is important in the human diet. The vitamin C in beetroot was 15.3299 mg/100 g, which is comparable with the previous literature, 23.3 mg/100 g to 33 mg/100 g reported by Straus *et al.* [17].

Of all these vegetables, green chili gave the highest level of vitamin C at 49.18 mg/100 g. The green chili shade dried shows loss of vitamin C as compared to other fresh vegetables, due to the sensitivity of vitamin C to atmospheric conditions like oxygen, light, and temperature. From this result, it can be concluded that drying vegetables decreases the vitamin C content. The result of the present study is less consistent with the result of 40 mg/100 g reported by Bhosale and Arya [45]. The percentage contribution of vitamin C to total anti-oxidant activity is given Table 7. In general, the antioxidant activity of any plant is contributed by its vitamin C and polyphenols contents. The scientific contribution for studying the percentage contribution of ascorbic acid to total anti-oxidant activity relationship is that it shows the major contribution of antioxidant activity is by vitamin C.

Table 6. The comparison of vitamin C contents in the vegetables of present study with previous reported data.

No.	Name of vegetables	Vitamin C in mg/100 g	Reference
1	Beetroot	15.1	This study
		10.05-11.6	[48]
		23.3-33	[17]
		4.9	[50]
2	Cabbage	32.5	This study
		64.3	[42]
		47.2	[42]
		40	[45]
3	Carrot	11.05	This study
		12.2±0.5	[39]
		13.6	[42]
4	Cauliflower	17.00	This study
		20	[45]
		10.05	[42]
5	Eggplant	6.68	This study
		3.9-4.9	[40]
		7.4-22	[41]
		10.9	[39]
6	Green chilli	49.18	This study
		40	[45]
7	Lettuce	21.001	This study
		3.55-9.6	[47]
8	Swisschsrd	16.24±0.3	This study
		18.41±0.3	[43]
		18	[50]

Table 7. Relationship between vitamin C and antioxidant capacity in percentages.

No.	Sample	AA in mg/100 g	AOA in mg/100 g	Percentage (%)
1	Beetroot	15.38	36.68	41.90
2	Cabbage	32.27	100.94	32.70
3	Carrot	11.05	30.55	36.19
4	Cauliflower	17.08	42.98	39.74
5	Eggplant	6.38	12.48	30.96
6	Greenchii	49.18	106.9	46.00
7	Lettuce	21.99	63.47	34.58
8	Swisschard	16.24	44.24	36.45

Hint: the percentages = 15.38 x 100/36.68 = 41.9%.

The values of the percentage between the contents of vitamin C and the antioxidant activity of vegetables, the lowest percentage was 30.962% for eggplant and the highest percentage was 46% for green chili. There was a direct relationship between vitamin C contents and the antioxidant activity of vegetables. The higher vitamin C content resulted in vegetables with higher antioxidant activity. Using simple linear correlation, the relation between vitamin C content and antioxidant activity of vegetables was performed by Pearson correlation. There was a strong correlation between vitamin C content and antioxidant activity of vegetables (r = 0.950) (Figure 2). This relation shows the antioxidant activity in vegetables is mainly contributed by vitamin C.

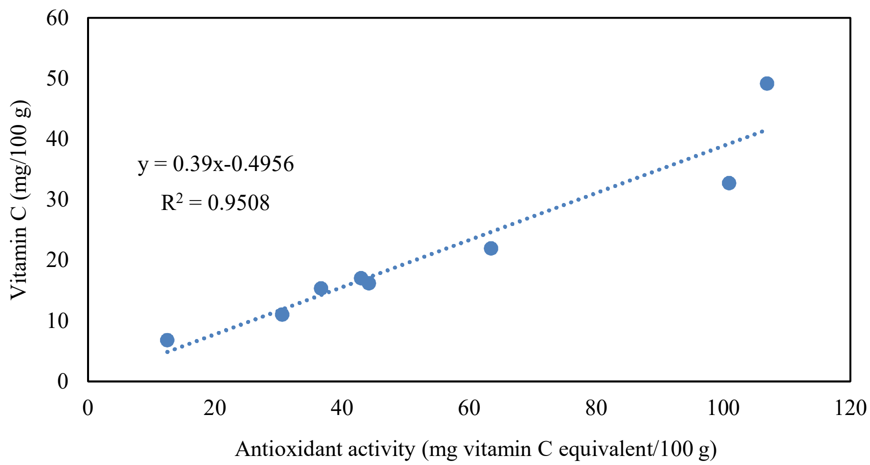

Figure 2. Relationship between vitamin C with antioxidant activity.

CONCLUSION

In the present study, eight types of vegetables which are commonly consumed in Addis Ababa, Ethiopia were analyzed for vitamin C contents by iodometric titration and antioxidant activity as DPPH assay by UV-spectrophotometer method. All these vegetables are excellent sources of vitamin C. All the studied vegetables have antioxidants, hence eating provides health benefits. The concentration of vitamin C decreases during the drying process of vegetables. From the results, eggplant had the least content of vitamin C 6.83 mg/100 g among the vegetables, and green chili had the highest content of vitamin C 49.18 mg/100 g of vitamin C from the vegetables. The synthesis of vitamin C in the individual vegetable is its inherent characteristics. The result of present study indicates that the green chili have higher ability to synthesize the vitamin C. Antioxidants of eight vegetables were observed by the DPPH scavenging assay.

Data availability

The data used to support the findings of this study are included within the article.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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