Rocz Panstw Zakl Hig 2024;75(1):21-33
http://wydawnictwa.pzh.gov.pl/roczniki_pzh/ https://doi.org/10.32394/rpzh.2024.0294

ORIGINAL ARTICLE

# DETERMINATION OF VITAMIN C IN RAW FRUIT AND VEGETABLE HOMOGENATES: DIETARY EXPOSURE AND HEALTH EFFECTS OF EXCESS INTAKE IN ADULTS AND CHILDREN

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## ABSTRACT

**Objective.** The aim of the study was to determine Vitamin C content in some fruits and vegetables (FAV) including apple, banana, orange, pineapple, watermelon, carrot and cucumber, sold in the local markets in Awka, Anambra State, Nigeria as well as Vitamin C content in two-component and three-component homogenates FAV. The work was also designed to investigate the dietary exposure and health effects of excess vitamin C intake in adults and children.

**Material and methods.** Vitamin C as total ascorbic acid (AA) after reduction of dehydroascorbic acid was analyzed using both titrimetric and spectrophotometric methods. The titrimetric method involved iodometric back-titration while the spectrophotometric method was done at an absorbance of 530 nm. The dietary exposure was evaluated as the total FAV intake multiplied by chemical concentration in the FAV whereas the health effect of excess vitamin C intake was conducted using the hazard quotient (HQ).

**Results.** The results revealed that Vitamin C for single fruits ranged from 11.76 - 41.17 mg/L for spectroscopic method and 16.9 – 31.84 mg/L for titrimetric method. Fruit homogenates showed Vitamin C concentrations of 14.70 – 220.58 mg/L and 17.23 – 209.09 mg/L for two-components homogenates: 29.41-132.35 mg/L and 31.05–113.10 mg/L for tri-components homogenates for spectrophotometric and titrimetric methods respectively. The results of dietary exposure and the health effects of excess vitamin C intake showed that children are more susceptible to health issues than adults in illnesses such as nausea, gastrointestinal pains, increased kidney stones and hyperactivity.

**Conclusion.** There is therefore the need for a national recommended dietary allowance for total ascorbic acid (AA) in FAV homogenates from a stakeholder point of view in Nigeria.

**Key words:** *Vitamin C, ascorbic acid, fruit, vegetables, FAV homogenates, food analysis, food composition, public health*

## INTRODUCTION

Fruits and vegetables (FAV) are a rich source of vitamins and minerals that are beneficial and critical for human health in preventing diseases like diverticulosis, gastrointestinal health, urinary tract infections, cardiovascular, and cancer, as well as reducing inflammation, preventing cell senescence, controlling weight, reducing systolic and diastolic blood pressure, and improving vision [16, 49, 51]. Fruits and vegetables contain high levels of dietary fiber, especially in their seeds, skin, pods, peels, hull, husk, stem, etc. [42]. They have a host of biochemicals such as phytochemicals, minerals, vitamins, organometals, and inorganic metals amongst others in diverse concentrations that are absorbed from soil nutrients and biotransformation of cellular interactions from DNA matrix in addition to photons from ultraviolet and visible spectra of the sun. These biochemicals may be nutritive and non-nutritive which are/may be critical for normal body functioning as their consumption is crucial to micronutrient availability in the body. Their importance is further emphasized by the fact that the human body is unable to synthesize them in sufficient amounts to meet daily recommended allowances [57], even though required only in small amounts. Studies have reported that the consumption of at least 400 g of FAV per day is considered adequate and that a global decrease in FAV consumption is responsible for the increasing cases of cardiovascular diseases and cancer [52, 67].

One of the most abundant vitamins in FAV is ascorbic acid also known as vitamin C. Vitamin C content varies for different FAVs especially due to the growing conditions of the plant and their exposure to sunlight [8, 33]. Muhammad *et al.* [31] and Uğur *et al.* [59] reported in their works that vitamin C is

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Publisher: National Institute of Public Health NIH - National Research Institute

usually higher in young FAV, while Ferrari *et al.* [17] and Mieszczakowska-Frąc et al. [28] noted that ascorbic acid stability decreases with an increase in temperature and pH as evidenced by its loss during food heat processing. It is also established that ascorbic acid gradually decreases over certain storage periods [71].

Numerous known roles of vitamin C include its role as a cofactor in numerous enzymatic interactions involving crucial genetic processes, such as the regeneration of collagen-containing connective tissues during human wound healing [25, 30]. Additionally, vitamin C helps with the absorption of inorganic iron, lowers plasma cholesterol levels, inhibits the development of nitrosamines, and strengthens the immune system [44]. Another major important function of vitamin C is its antioxidant activity by reaction with singlet oxygen and other free radicals to reduce the risk of arteriosclerosis, which aids the body in preventing certain cancers, reduce oxidative damage including the oxidative modification of low-density lipoproteins which cause cardiovascular diseases, flu, muscular degeneration and cataract [63, 65]. Vitamin C also has an important role in the synthesis of protein as one of the amino acids used to build collagen-hydroxyproline is only synthesized on the availability of amino acids. Its deficiency notably leads to diminished collagen synthesis, which contributes to more severe symptoms of scurvy.

Laboratory studies have shown that ascorbic acid is capable of preventing the replication of HIV, with the ability to act as an excellent supplement for HIV patients [9]. Renker et al. [45] reported that consumption of Vitamin C at levels of 2 grams daily may help to control hepatitis, prevent flu and speed up recovery from influenza. Vitamin C also possibly decreases the incidence of urinary tract infection by increasing the acidity of urine, which makes it an inhospitable host for bacteria [6].

The consumption of Vitamin into the body may sometimes be challenging to people who are pharmacophobic but yet require it for proper body function. For this set of people, the consumption of fruit to supplement this, either singly or in blends becomes inevitable. Attempts had been made to determine the concentration of vitamin C in some selected FAV. Nonetheless, there is a lack of literature on dietary exposure and health effects of excess vitamin C intake in people. Therefore, the present study seeks to compare the concentration of vitamin C in some FAV and their homogenates using two analytical methods, as well as the dietary exposure and health effects of excess vitamin C intake in adults and children.

## MATERIALS AND METHODS

*Sample collection and preparation*

Mature FAV: orange, apple, pineapple, carrot, watermelon, cucumber, and banana were randomly purchased from different sellers in a local market in Awka, Anambra State, Southeast region of Nigeria. The samples, thoroughly washed with distilled water before being chopped into 100 g each were weighed and the juice extracted using a juice extractor. The juices were filtered with muslin cloth to remove pulps, seeds, and other particles before being stored in labelled plastic bottles (n = 7) as A = apple (*Malus malus*); B = banana (*Musa paradisiaca*); C = carrot *(Daucus carota)*; D = cucumber (*Cucumus sativus*); E = orange *(Citrus sinensis)*; F = pineapple *(Ananas comosus)*; G = watermelon (C*itrullus lanatus).* Then, the juices were blended accordingly, and homogenized to produce the homogenates (n = 21) for two blends and (n = 15) for blends of three amounting to $N = \sum n = 43$ before further analyses were done. All the samples were analyzed in triplicate, and the concentrations of ascorbic acid were presented as the mean of the replicate values.

*Preparation of stock and standard solution of ascorbic acid*

Standard solution of ascorbic acid was prepared by dissolving an accurate weight of 0.01 g of the standard ascorbic acid (BASF) in a small amount of oxalic acid solution (0.5%) and then completed to 100 mL with the same solution to obtain a concentration of 100 µg/mL. A series of dilutions of 15, 20, 25, 30, and 35 µg/mL were prepared from stock ascorbic acid solution.

*Preparation of standard calibration curve of ascorbic Acid*

Standard calibration curve of ascorbic acid was established by graphing concentrations versus absorbance of ascorbic standard solutions by taking 5 mL of each standard solution and put in a test tube; then 0.5 mL of $KMnO_4$ (Spectrum Chemical Mfg.), solution was added. This solution was left to stand for 5 min. The absorbance of this standard solution was read at 530 nm against blank.

*Vitamin C analysis by spectrophotometric method*

10 mL of each sample was transferred into a 50 mL volumetric flask and 25 mL of oxalic acid (BASF) was added and gently mixed to get a homogenous mixture. It was then made up to mark with the same solution and the resulting solution was centrifuged for 15 min. Exactly 5 mL of each supernatant was transferred into a test tube, and 0.5 mL of $KMnO_4$ was added. The contents of each sample were thoroughly mixed and allowed to stand for 5 minutes before the

solutions were read at 530 nm against blank by UV-Vis spectrophotometer (Malvern Panalytical).

*Calibration curve*

The absorbances of the standard ascorbic acid were tabulated in Table 1 and used to determine the calibration curve by plotting the absorbance against concentration as shown in Figure 1.

Table 1. Concentration and absorbance of the standard

| Concentration (µg/mL) | Absorbance |
|---|---|
| 15 | 0.05 |
| 20 | 0.06 |
| 25 | 0.08 |
| 30 | 0.10 |
| 35 | 0.13 |

After determination of the ƛ of the coloured complex at 530 nm using 752N spectrophotometer, the absorbance of all the standards and concentration is known. The concentration of the vitamin C in the sample was calculated from the relation: y = 0.0034x .

Equation was extracted from the calibration curve in Figure 1 where x is the concentration of the vitamin C in the sample and y is the absorbance of the sample at 530 nm.

added. Each was titrated with 0.015 M $IO_3$ (BASF) till a blue-black end point was reached. Concentration in mg/L of ascorbic acid in the samples was calculated as a function of iodine used up.

*Dietary exposure of Vitamin C*

The dietary exposure of Vitamin C was conducted according to method used by Kim *et al.,* (2015). The authors suggested that dietary exposure is the sum of food intake (consumption rate) with chemical concentration in FAV sources (vitamin C from spectrophotometric method) and is given as:

$$\textit{Dietary exposure} = \sum_{i=1}^{n} (\textit{Food intake} \times \textit{Chemical concentration in FAV})$$

Where:
Food intake = daily consumption rate using on-the-spot assessment from market survey (67, 68]
Chemical concentration = spectroscopic result of FAV

The food intake (FI) was determined from market survey conducted in Eke-Awka, Anambra State, Southeastern Nigeria using purchasing strength, taste, availability, seasonal variation, frequency, mixing period, preparation style and farming style across different locations, which was made to develop the

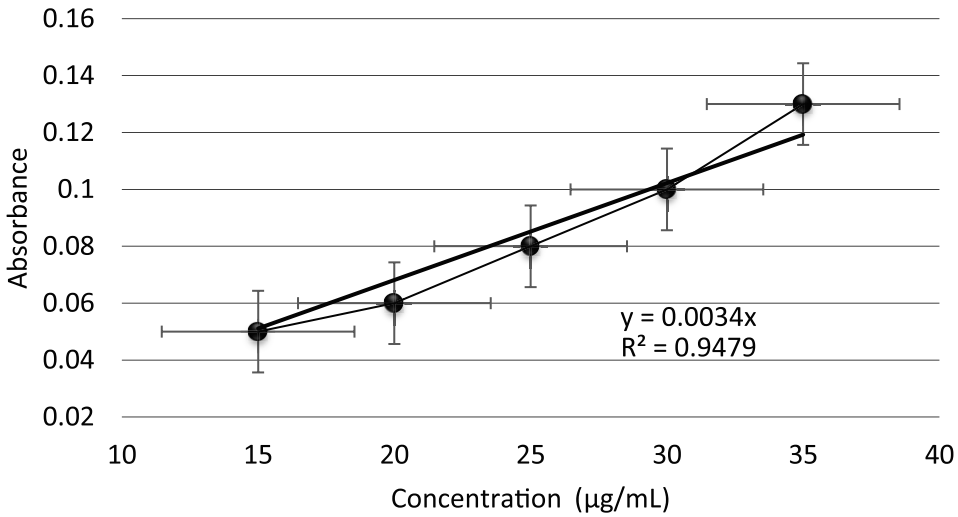


Figure 1. Standard calibration curve of vitamin C

*Vitamin C analysis by titration method*

A 5 mL aliquot of each sample was extracted with 20 mL of oxalic acid, followed by centrifugation at 1800 rpm for 10 mins. The supernatant was decanted and made up to 200 mL mark in a volumetric flask before 1 mL of each sample was put in 200 mL flask and made up to mark with distilled water. 10 mL of each was measured in a conical flask and then 5 mL of 0.2 M KI, 2.5 mL of 1.0 M HCl and a few drops of starch indicator (Spectrum Chemical Mfg.) solution

daily consumption rate (DCR) [7, 21, 22, 26]. The dietary intake was evaluated with 20% mid limit and 95% upper limit to minimize errors potential from on-the-spot assessment conducted from uncertainty [64].

Although for health concerns, there is a need to evaluate with body weight and reference guideline for adverse health intake quotient, which is given as hazard quotient (HQ) [37, 38, 40, 41] as shown in equation below.

$$Hazard\ quotient = \frac{Dietary\ exposure}{body\ weight \times References\ guideline}$$

Where:
Body weight: 80 kg (adult, 16 – 30 years), 15 kg (children, 0 – 15) from site specific assessment conducted on 100 random respondents
Reference guideline = Recommended dietary allowance (RDA) [32].

Results obtain with the spectrophotometric method were used to calculate dietary exposure because we assumed this method is more specific and sensitive than the titrimetric method.

*Statistical analysis*

Statistical analyses were done using Microsoft Excel version 2010. Variations were considered significant at $p<0.05$ and results are presented as mean.

## RESULTS AND DISCUSSION

**Concentration matrix using the two analytical methods**

Tables 2, 3 and 4 depict the concentration of vitamin C for spectrophotometric and titrimetric methods in FAV, two-component and tri-component homogenates respectively.

Orange and pineapple showed the highest vitamin C contents for both methods as seen in Table 2, while cucumber showed the least availability of vitamin C in both methods. The vitamin C content reported by Mohammed et al. [29] and Isam et al. [23] for watermelon, orange, cucumber, apple, and banana are lower compared to the present study, likely because of the experimental methods and the geographical area of sampling of the fruits. Also, the variation in results for this study and other reports can be explained based on climatic conditions as light and temperature are factors that affect vitamin C contents in fruits and vegetables and have been reported to affect the chemical composition of horticultural crops. The use of nitrogen fertilizers has also been fingered as a potential alternative to plant nutrients [50, 54].

Table 3 shows the results of vitamin C in samples of two-component homogenates FAV, revealing that the highest concentration of vitamin C was recorded in orange mixtures such as orange-pineapple, orange-apple and orange-watermelon. Citrus fruits have a high vitamin C content, which was enhanced when combined with other fruits that have comparable ascorbic acid concentrations. Research has demonstrated that vitamin C is the main antioxidant found in citrus fruits [69]. The lowest vitamin C content was found mostly in apple mixtures, excluding those containing orange and pineapple. Even though apples are not a significant source of vitamin C [62], the majority of commercially available apple juices are fortified to contain one or more reference dietary intake daily values, although ascorbic acid in apples degrades very quickly [58]. Nonetheless, two-component homogenate FAVs showed improved vitamin C content compared to single FAV juices.

In the tri-component homogenate FAVs shown in Table 4, highest vitamin C content was seen in cucumber-orange-pineapple and orange-pineapple-watermelon mixtures, corroborating the position of orange and pineapple as high vitamin C fruits. The lowest vitamin C content was recorded in carrot-cucumber-watermelon and apple-banana-cucumber mixtures. Again, as in two-component homogenate FAVs, vitamin C was higher than in tri-component homogenate FAVs than single fruit/vegetable. The results show that homogenate FAV extracts could contribute substantially to the 45 mg WHO [68] daily recommended dietary allowance of vitamin C. The results obtained are in agreement with the results reported by Awsi and Er-Dorcus [5], where maximum vitamin C concentration was recorded in pineapple juice blended with orange and carrot juice. Jain and Khurdiya [24] also reported that when Indian gooseberry juice was blended with other fruit juices, their vitamin C content was boosted.

Yoshizaki *et al.* [70] noted that mixed fruit juices have epidemiological advantages such as in reducing

Table 2. Concentration of FAV (mg/100g)

| Sample codes | Sample | Spectroscopic Method (530nm) | Titrimetric Method |
|---|---|---|---|
| A | Apple | 26.47 | 26.58 |
| B | Banana | 20.58 | 31.41 |
| C | Carrot | 17.64 | 29.64 |
| D | Cucumber | 11.76 | 16.79 |
| E | Orange | 41.17 | 32.80 |
| F | Pineapple | 38.23 | 31.84 |
| G | Watermelon | 11.76 | 26.74 |

Table 3. Concentration of two-component homogenates (mg/100 g)

| Sample | Two blends | Spectroscopic Method (530nm) | Titrimetric Method |
|---|---|---|---|
| AB | Apple + Banana | 38.23 | 35.64 |
| AC | Apple + Carrot | 47.05 | 37.54 |
| AD | Apple + Cucumber | 35.29 | 40.71 |
| AE | Apple + Orange | 161.78 | 155.20 |
| AF | Apple + Pineapple | 70.58 | 71.60 |
| AG | Apple + Watermelon | 35.29 | 34.01 |
| BC | Banana + Carrot | 35.29 | 38.02 |
| BD | Banana + Cucumber | 38.23 | 43.72 |
| BE | Banana + Orange | 50.00 | 48.24 |
| BF | Banana + Pineapple | 97.05 | 99.78 |
| BG | Banana + Watermelon | 44.11 | 42.21 |
| CD | Carrot + Cucumber | 14.70 | 17.23 |
| CE | Carrot + Orange | 47.05 | 41.82 |
| CF | Carrot + Pineapple | 50.00 | 43.24 |
| CG | Carrot + Watermelon | 58.82 | 41.66 |
| DE | Cucumber + Orange | 35.29 | 32.16 |
| DF | Cucumber + Pineapple | 155.88 | 160.78 |
| DG | Cucumber +Watermelon | 29.44 | 28.96 |
| EF | Orange + Pineapple | 220.58 | 209.09 |
| EG | Orange + Watermelon | 135.35 | 136.38 |
| FG | Pineapple + Watermelon | 79.41 | 68.39 |

Table 4. Concentration of tri-component homogenates (mg/100 g)

| Sample codes | Tri-component homogenates | Spectroscopic Method (530nm) | Titrimetric Method |
|---|---|---|---|
| ABC | Apple + Banana + Carrot | 64.70 | 63.36 |
| ABD | Apple + Banana + Cucumber | 55.88 | 54.69 |
| ABE | Apple +Banana + Orange | 76.47 | 66.53 |
| ABF | Apple + Banana + Pineapple | 70.58 | 65.89 |
| ABG | Apple + Banana + Watermelon | 61.76 | 57.73 |
| BCD | Banana + Carrot + Cucumber | 32.35 | 34.37 |
| BCE | Banana + Carrot + Orange | 88.23 | 75.08 |
| BCF | Banana + Carrot + Pineapple | 82.35 | 71.28 |
| BCG | Banana + Carrot + Watermelon | 44.11 | 32.63 |
| CDE | Carrot + Cucumber + Orange | 61.76 | 65.26 |
| CDF | Carrot + Cucumber + Pineapple | 29.41 | 31.05 |
| CDG | Carrot + Cucumber + Watermelon | 50.00 | 51.32 |
| DEF | Cucumber + Orange + Pineapple | 132.35 | 112.60 |
| DEG | Cucumber + Orange + Watermelon | 70.58 | 75.08 |
| EFG | Orange + Pineapple + Watermelon | 105.88 | 113.10 |

the risk of some cancers, metabolic disorders, cardiovascular disease and stroke. Rossi et al. [46] further noted that they may contribute significantly in increasing protective serum antioxidants. Nonetheless, mixed fruit juices do not automatically translate to improved vitamin C and mineral concentration, but may be based on FAV type. This can be seen in the USDA (SR21) database where black currant, which as a single fruit, on its own contains more vitamin C and minerals than any group of mixed fruits [12].

The efficiency of the method used in ascertaining concentration for vitamin C cannot be attributed to any single method as it varied indiscriminately. Nonetheless, the spectrophotometric method seemed to give a more stable result. Isam et al. [23] in a comparative study noted that there was no significant difference between the two methods, but the spectrophotometric method has been favoured over the titrimetric method. However, these discrepancies may be due to titration errors and the difficulty in ascertaining the end-point where the extracts are coloured, especially the reddish-purplish colours. For the iodometric titration method which is based on an oxidation-reduction reaction, there may be other factors such as the presence of other reducing substances besides ascorbic acid in the foods. Holloway et al. [20] noted that molecules like phenols, sulphydryls, and triose reductones; and ferrous, cuprous, or sulphite ions can reduce the dye giving rise to high and false titration results. However, Nweze et al. [34] also noted that interferences may be overcome by pH adjustment to reduce the speed of the reaction, such that most interfering materials react very much slower than ascorbate.

**Comparison of the two methods**

The concentrations of Vitamin C for both spectroscopic method and titration method of determination showed good efficiency of quantification, as spectrophotometric method was influenced by sensitivity and selectivity across all samples and respective blends in comparison with titrimetric method. Several researchers have focused on different methods of determining ascorbic acid (vitamin C): El Shara and Mussa [15] and Adebayo [3] analyzed for Vitamin C using UV-Vis spectrophotometer and titration in vegetables and fruits. They revealed that UV-Vis method provides higher sensitivity in ascorbic acid concentration than titration, as they affirmed that the concertation matrix is dependent on different factors such as geography and location, variety in species, harvest period, temperature, storage duration and temperature, handling and preconditioning (ripening stage), which can invariably lead to contradictory results as seen in diverse researches [18, 56].

Hagos et al. [18] assessed for ascorbic acid (Vitamin C) using ATR-FTIR (Attenuated total reflectance – Fourier transformed infrared spectroscopy and UV-Vis methods in aqueous extract of pumpkin, as UV-Vis method showed high accuracy, sensitivity and precision as well as fast determination than ATR-FTIR for quantitative and qualitative processes.

Sharma et al., [48] assessed vitamin C concentration in commercial fruit juice and fresh fruits sold in Nepal using titration, thin-layer chromatography and UV-Vis, as they observed that UV-Vis was better than the other two methods.

Several other researchers [1, 2, 4, 11, 36, 47, 56, 73] have utilized different analytical methods such as chromatography (solid, liquid, gas), titrimetric, voltammetry, fluorometry, potentiometry, UV-Vis, FTIR, capillary electrophoresis and reverse phase for determination of ascorbic acid (Vitamin C) from fresh fruits, vegetables and processed/extract fruit juices; as UV-Vis has been assessed to meet good specificity, sensitivity, rapid, accurate and simple in operation. Although the analytical methods have diverse extraction procedures, and analytical technique and experimental variation differences, there is a close relationship in terms of linearity, validity, accuracy and reproductivity across their respective analytical results as Abe-Matsumoto et al. [1] stated that "*LOQ (limit of quantification) and LOD (limit of detection) are not critical for choosing best method*" but reliability and sensitivity are critical in vitamin C studies.

**Dietary exposure**

The dietary exposure to Vitamin C was conducted for fruits/vegetables and FAV homogenates to estimate the likely exposure level of food chemicals for a population group in addition to associated adverse or health risks associated with continual exposure to extreme concentration [27, 53]. The daily consumption rate using on-the-spot assessment from a market survey [67, 68] is shown in Table 5.

**Health effect of excess vitamin C intake**

According to the National Institute of Health [32], vitamin C has minimal toxicity and does not portend any serious adverse health conditions, while it is critical to note that 70 – 90% of vitamin C is absorbed in cells, tissues, and plasma from moderate intake of 30 – 180 mg/day and less than 50% unabsorbed that are not metabolized are excreted as urine or sweat as salt. The commonest illnesses associated with vitamin C non-metabolism are nausea, abdominal spasms, gastrointestinal disturbances, and diarrhoea [21, 22, 60].

Hazard quotient (HQ) was evaluated using the recommended dietary allowance (RDA) of 45 mg/day [68] for children and adults in addition to lower and upper limits of 20% and 95%, which shows that in Figure 2 and Table 6 using HQ reference of 1.0 to cause adverse health effects implies that children at 95% tolerance were above one for age group between 0.-15 years might experience increase in carbon dioxide ($CO_2$) in the intestine from oxidized (dehydroascorbic acid) form of unabsorbed vitamin C in high dose causing nausea [72].

There are several side effects associated with large doses (exposure) of vitamin C when it exceeds RDAs for diverse age groups, as it is known that fruits/vegetables have different concentrations, which

Table 5. Consumption rate of analyzed fruit/vegetable and FAV homogenates in (g/day) using on-the-spot assessment

| Sample codes | Sample | On-the-spot assessment |
|---|---|---|
| A | Apple | 0.6 |
| B | Banana | 25.0 |
| C | Carrot | 0.13 |
| D | Cucumber | 6.5 |
| E | Orange | 5.7 |
| F | Pineapple | 3.5 |
| G | Watermelon | 5.2 |
| AB | Apple + Banana | 21.6 |
| AC | Apple + Carrot | 1.7 |
| AD | Apple + Cucumber | 2.5 |
| AE | Apple + Orange | 2.1 |
| AF | Apple + Pineapple | 1.9 |
| AG | Apple + Watermelon | 2.3 |
| BC | Banana + Carrot | 12.2 |
| BD | Banana + Cucumber | 20.1 |
| BE | Banana + Orange | 19.1 |
| BF | Banana + Pineapple | 22.1 |
| BG | Banana + Watermelon | 18.5 |
| CD | Carrot + Cucumber | 1.4 |
| CE | Carrot + Orange | 2.4 |
| CF | Carrot + Pineapple | 4.1 |
| CG | Carrot + Watermelon | 2.5 |
| DE | Cucumber + Orange | 5.0 |
| DF | Cucumber + Pineapple | 4.6 |
| DG | Cucumber +Watermelon | 3.0 |
| EF | Orange + Pineapple | 6.1 |
| EG | Orange + Watermelon | 6.0 |
| FG | Pineapple + Watermelon | 3.9 |
| ABC | Apple + Banana + Carrot | 12.9 |
| ABD | Apple + Banana + Cucumber | 10.1 |
| ABE | Apple +Banana + Orange | 21.9 |
| ABF | Apple + Banana + Pineapple | 17.0 |
| ABG | Apple + Banana + Watermelon | 11.4 |
| BCD | Banana + Carrot + Cucumber | 9.2 |
| BCE | Banana + Carrot + Orange | 11.0 |
| BCF | Banana + Carrot + Pineapple | 12.9 |
| BCG | Banana + Carrot + Watermelon | 20.0 |
| CDE | Carrot + Cucumber + Orange | 3.3 |
| CDF | Carrot + Cucumber + Pineapple | 4.9 |
| CDG | Carrot + Cucumber + Watermelon | 2.0 |
| DEF | Cucumber + Orange + Pineapple | 2.4 |
| DEG | Cucumber + Orange + Watermelon | 1.8 |
| EFG | Orange + Pineapple + Watermelon | 7.1 |

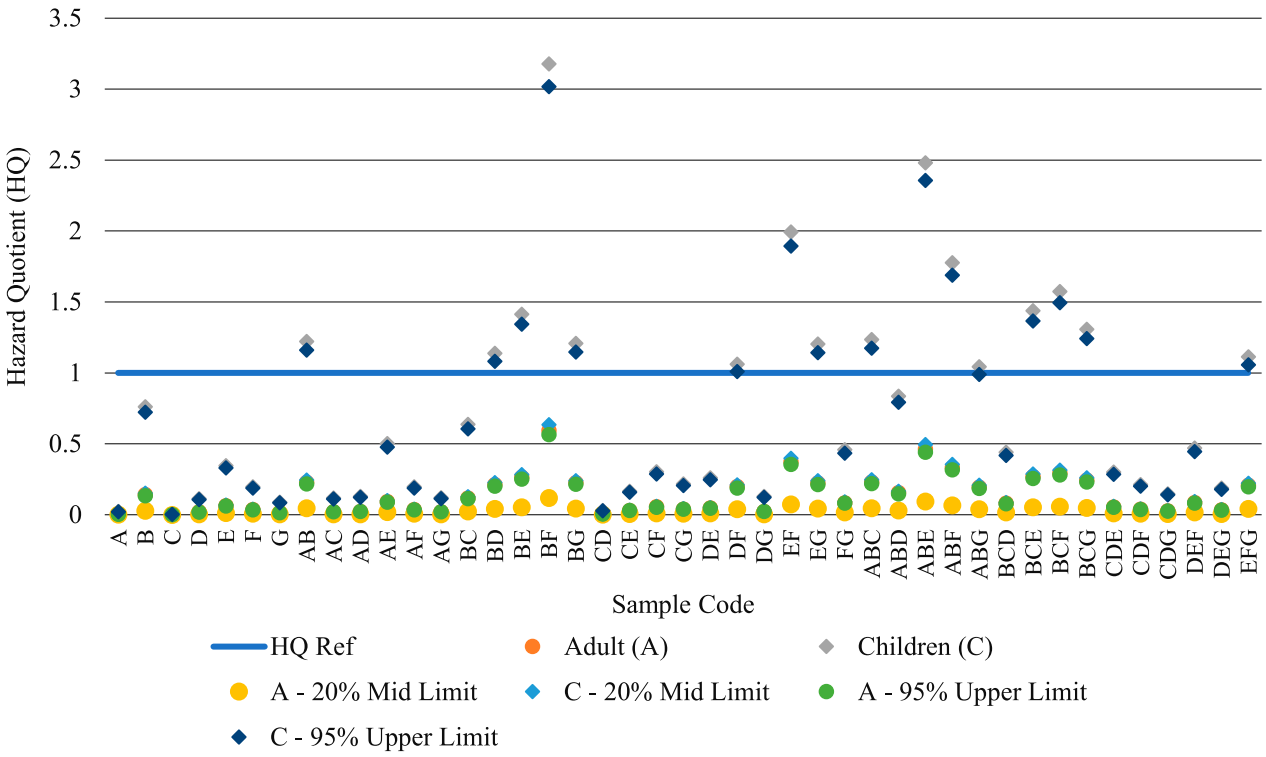


Figure 2. Hazard quotient of vitamin C in fruits/vegetables and FAV homogenates

has been reported to ischemic stroke, cause enamel erosion during chewing, increase in renal stones and allergic response [ 14, 22, 55, 60]. Although diarrhea and abdominal pain may occur from excretion of unmetabolized vitamin C for a few periods of 1 – 2 weeks, it can be managed by reducing FAV intake or dividing the cumulative amount or frequency of intake into multiple doses in minimized forms [13, 19, 72].

Vitamin C has been associated with iron (Fe)-induced oxidative stress from oxidable health metals such as lead and mercury that are known toxins causing blood related illness such as leukaemia [ 35, 39, 72]. An extensive study conducted by Pullar *et al.,* [43] has shown that high dose of vitamin C can cause elevated mood in male tertiary students in New Zealand, as conflicting analogies stated that there might be slight to strong correlation of vitamin C in high dose to cause depression [ 7, 66].

Therefore, it is advantageous to state that this study was conducted as a dose-response-effect relationship quotient to assess vitamin C intake from fruits/vegetables and FAV homogenates in both adults and children. Hence, from Figure 2, children are relatively at risk from immense exposure. There might be issue of uncertainty across the utilization of on-the-spot assessment conducted for dietary intake of these fruits in addition to overestimation or underestimation of results in the study, as it is a known fact that vitamin C has immense functionality to improve human health, quality of life and treat illnesses/diseases in addition to other essential elements and chemicals that are critical for dietary input from different race, locality and food style that might have increase or decrease vitamin C concentration [10, 61, 67].

## CONCLUSION

The study has shown that FAV homogenate juices, especially those containing orange and pineapple, showed higher improvements in Vitamin-C content compared to single fruit/vegetable juices, and can contribute substantially to daily recommended dietary allowance. The two methods (spectrophotometry and titration) analyzed indicated that the concentration of vitamin C in single fruit/vegetable juice ranged between 11.76 – 41.17 mg/100g and 16.79 – 32.80 mg/100 g; while two-component FAV homogenates ranged between 14.70 – 220.58 mg/100g and 17.23 – 209.09 mg/100 g; and tri-component FAV homogenates ranged between 29.41 – 132.35 mg/100g and 31.05 – 113.10 mg/100g respectively. There was little or no observed difference between spectrophotometric and the titrimetric method. However, the spectrophotometric method is favourable and satisfactory for vitamin C determination because of its sensitivity, ease and minimal errors. The dietary exposure and health effect of vitamin C excess intake showed that children are susceptible to have health concerns such as nausea, gastrointestinal pains, increase renal stone and excessive. With the improved vitamin-C content available in FAV homogenates, it

Table 6. Hazard Quotient of Vitamin C in FAV and FAV homogenates

| Sample codes | Adult (A) | Children (C) | A - 20% Mid Limit | C - 20% Mid Limit | A - 95% Upper Limit | C - 95% Upper Limit | HQ Reference |
|---|---|---|---|---|---|---|---|
| A | 0.004 | 0.024 | 9E-04 | 0.005 | 0.004 | 0.022 | 1 |
| B | 0.143 | 0.762 | 0.029 | 0.152 | 0.136 | 0.724 | 1 |
| C | 6E-04 | 0.003 | 1E-04 | 7E-04 | 6E-04 | 0.003 | 1 |
| D | 0.021 | 0.113 | 0.004 | 0.023 | 0.02 | 0.108 | 1 |
| E | 0.065 | 0.348 | 0.013 | 0.07 | 0.062 | 0.33 | 1 |
| F | 0.037 | 0.198 | 0.007 | 0.04 | 0.035 | 0.188 | 1 |
| G | 0.017 | 0.091 | 0.003 | 0.018 | 0.016 | 0.086 | 1 |
| AB | 0.229 | 1.223 | 0.046 | 0.245 | 0.218 | 1.162 | 1 |
| AC | 0.022 | 0.118 | 0.004 | 0.024 | 0.021 | 0.113 | 1 |
| AD | 0.025 | 0.131 | 0.005 | 0.026 | 0.023 | 0.124 | 1 |
| AE | 0.094 | 0.503 | 0.019 | 0.101 | 0.09 | 0.478 | 1 |
| AF | 0.037 | 0.199 | 0.007 | 0.04 | 0.035 | 0.189 | 1 |
| AG | 0.023 | 0.12 | 0.005 | 0.024 | 0.021 | 0.114 | 1 |
| BC | 0.12 | 0.638 | 0.024 | 0.128 | 0.114 | 0.606 | 1 |
| BD | 0.213 | 1.138 | 0.043 | 0.228 | 0.203 | 1.081 | 1 |
| BE | 0.265 | 1.415 | 0.053 | 0.283 | 0.252 | 1.344 | 1 |
| BF | 0.596 | 3.177 | 0.119 | 0.635 | 0.566 | 3.019 | 1 |
| BG | 0.227 | 1.209 | 0.045 | 0.242 | 0.215 | 1.148 | 1 |
| CD | 0.006 | 0.03 | 0.001 | 0.006 | 0.005 | 0.029 | 1 |
| CE | 0.031 | 0.167 | 0.006 | 0.033 | 0.03 | 0.159 | 1 |
| CF | 0.057 | 0.304 | 0.011 | 0.061 | 0.054 | 0.289 | 1 |
| CG | 0.041 | 0.218 | 0.008 | 0.044 | 0.039 | 0.207 | 1 |
| DE | 0.049 | 0.261 | 0.01 | 0.052 | 0.047 | 0.248 | 1 |
| DF | 0.199 | 1.062 | 0.04 | 0.212 | 0.189 | 1.009 | 1 |
| DG | 0.025 | 0.131 | 0.005 | 0.026 | 0.023 | 0.124 | 1 |
| EF | 0.374 | 1.993 | 0.075 | 0.399 | 0.355 | 1.894 | 1 |
| EG | 0.226 | 1.203 | 0.045 | 0.241 | 0.214 | 1.143 | 1 |
| FG | 0.086 | 0.459 | 0.017 | 0.092 | 0.082 | 0.436 | 1 |
| ABC | 0.232 | 1.236 | 0.046 | 0.247 | 0.22 | 1.175 | 1 |
| ABD | 0.157 | 0.836 | 0.031 | 0.167 | 0.149 | 0.794 | 1 |
| ABE | 0.465 | 2.481 | 0.093 | 0.496 | 0.442 | 2.357 | 1 |
| ABF | 0.333 | 1.778 | 0.067 | 0.356 | 0.317 | 1.689 | 1 |
| ABG | 0.196 | 1.043 | 0.039 | 0.209 | 0.186 | 0.991 | 1 |
| BCD | 0.083 | 0.441 | 0.017 | 0.088 | 0.079 | 0.419 | 1 |
| BCE | 0.27 | 1.438 | 0.054 | 0.288 | 0.256 | 1.366 | 1 |
| BCF | 0.295 | 1.574 | 0.059 | 0.315 | 0.28 | 1.495 | 1 |
| BCG | 0.245 | 1.307 | 0.049 | 0.261 | 0.233 | 1.242 | 1 |
| CDE | 0.057 | 0.302 | 0.011 | 0.06 | 0.054 | 0.287 | 1 |
| CDF | 0.04 | 0.213 | 0.008 | 0.043 | 0.038 | 0.203 | 1 |
| CDG | 0.028 | 0.148 | 0.006 | 0.03 | 0.026 | 0.141 | 1 |
| DEF | 0.088 | 0.471 | 0.018 | 0.094 | 0.084 | 0.447 | 1 |
| DEG | 0.035 | 0.188 | 0.007 | 0.038 | 0.034 | 0.179 | 1 |
| EFG | 0.209 | 1.114 | 0.042 | 0.223 | 0.198 | 1.058 | 1 |

will be an important source of the nutrient for this class of individuals. Therefore, there is need to develop a national recommended dietary intake in Nigeria to assist all value chain (medical, industrial players, ministries, department, and agencies of government) to be equipped with information as regards essential nutrients.

Data availability statement: All data and materials are available from Authors, on reasonable request.

**Disclosure statement conflict of interest**

No potential conflict of interest was reported by the authors.

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Received: 02.10.2023
Accepted: 08.03.2024

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