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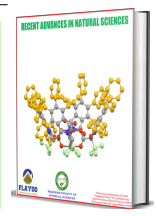

Evaluation of antioxidant capacity and nutritional components of five locally consumed fruits in Eastern Nigeria

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ABSTRACT

The nutraceutical richness of locally cultivated fruits in Eastern Nigeria remains poorly documented, limiting guidance for dietary management of oxidative stress-related disorders. This study quantified the vitamin C content, total flavonoids, total antioxidants, and reducing properties of five commonly consumed fruits: cashew (Anacardium occidentale), star apple (Chrysophyllum albidum), pawpaw (Carica papaya), garden egg (Solanum melongena), and watermelon (Citrullus lanatus). Spectroscopic methods were employed to assay total antioxidants, flavonoids, and reducing properties using gallic acid, rutin, and trichloroacetic acid as standards, respectively, while vitamin C was determined by titrimetric analysis using 2,6-dichlorophenol indophenol. Results (mean ± SD, mg/100 g) showed that pawpaw had the highest vitamin C (98.50 ± 0.01), total flavonoids (103.11 ± 0.01), total antioxidants (109.17 ± 0.04), and reducing properties (63.23 ± 0.07), followed by star apple, watermelon, garden egg, and cashew. A strong positive correlation (r = 0.87) was observed between total flavonoid content and reducing power, indicating that flavonoids significantly contribute to antioxidant activity. These findings provide evidence supporting increased consumption of pawpaw, star apple, and watermelon to mitigate oxidative stress, compensate for nutrient deficiencies, and promote public health in Eastern Nigeria..

1. INTRODUCTION

Oxidative stress arises from an imbalance between the generation of reactive oxygen species (ROS) and the antioxidant defense mechanisms in biological systems, leading to cellular and molecular damage [1–3]. Excessive ROS production such as hydroxyl radical (OH), superoxide anion (O_2^*), hydrogen peroxide (H_2O_2), and singlet oxygen can initiate lipid peroxidation, protein denaturation, DNA fragmentation, and enzyme inactivation [4, 5]. These oxidative events are key contributors to pathological conditions including cardiovascular diseases [3, 6], diabetes mellitus, neurodegenerative disorders, inflammation, and premature aging [7, 8].

Antioxidants are compounds capable of donating electrons or hydrogen atoms to neutralize free radicals, thereby terminating

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the chain reactions of lipid and protein oxidation [6, 9]. They act through several mechanisms: by scavenging free radicals, chelating metal ions, and decomposing peroxides [10]. Naturally occurring antioxidants in fruits and vegetables particularly polyphenols, flavonoids, carotenoids, and vitamins (A, C, and E) have been shown to reduce oxidative stress and promote human health [1, 10].

In Nigeria, fruits such as *Psidium guajava* (guava), *Ananas comosus* (pineapple), *Citrus sinensis* (orange), *Carica papaya* (pawpaw), and *Persea americana* (avocado) are widely consumed for their nutritional and ethnomedicinal value. These fruits are integral to the local diet in Eastern Nigeria, where they are traditionally associated with improved digestion, enhanced immunity, and management of oxidative stress-related ailments. Despite their popularity, there is limited scientific documentation of their proximate composition, vitamin profile, and antioxidant capacity under standardized biochemical evaluation [1, 10].

Recent studies across tropical regions have demonstrated the relevance of indigenous fruits as sources of bioactive compounds with significant antioxidant potential [11–13]. For instance, Chijindu *et al.* [14] reported high phenolic and flavonoid contents in tropical fruits from Southwest Nigeria, while Phiri *et al.* [15] observed a strong correlation between vitamin C and DPPH scavenging activity in selected African fruits. Such findings underscore the need to assess locally available fruits from Eastern Nigeria, which remain underexplored in the context of nutritional and health-promoting properties.

Therefore, this study aims to determine the proximate composition, vitamin content, and antioxidant activities of selected fruits commonly consumed in Eastern Nigeria. The results will provide valuable data for nutritional policy development and highlight the potential of these fruits in functional food and nutraceutical applications

2. MATERIALS AND METHOD

2.1. SAMPLE COLLECTION AND PREPARATION

Five varieties of fresh, ripe fruits *Anacardium occidentale* (cashew), *Chrysophyllum albidum* (African star apple), *Carica papaya* (pawpaw), *Solanum aethiopicum* (garden egg), and *Citrullus lanatus* (watermelon) were purchased from Eke Agbani Market in Nkanu East Local Government Area, Enugu State, Nigeria. The market lies within the geographical coordinates of latitude 6°18′12″ N and longitude 7°33′45″ E. The selected fruits were chosen based on their high local consumption and reported phytochemical potential.

Each fruit sample was sorted to remove damaged or unripe portions, thoroughly rinsed with distilled water to eliminate surface contaminants, and air-dried at ambient temperature. The edible portions were separated manually using sterile stainless-steel knives to prevent metal contamination, then homogenized using a pre-cleaned electric blender (Model Qlink, 1200 W) under aseptic conditions. The blended fruit pulps were stored in amber glass containers, labeled appropriately, and kept at 4 °C prior to further analysis to minimize enzymatic degradation and oxidative loss of antioxidant constituents.

All sample preparation procedures were performed according to standard guidelines for antioxidant analysis and phytochemical extraction to ensure comparability and reproducibility of results [16, 17].

2.2. DETERMINATION OF TOTAL ANTIOXIDANT CONTENT

The total antioxidant content (TAC) of the fruit extracts was determined using a modified Folin–Ciocalteu colorimetric method as described by Lawag *et al.* [18] and Lamptey *et al.* [19] with slight modifications. Gallic acid was employed as the calibration standard.

Briefly, 1.0 mL of each fruit extract or gallic acid standard solution (10, 20, 30, 40, 50, and 100 mg/L) was transferred into clean test tubes, followed by the addition of 9.0 mL of distilled water. Subsequently, 1.0 mL of Folin–Ciocalteu's reagent was added to each tube, and the mixture was vortexed thoroughly to ensure homogeneity. After standing for 5 minutes at room temperature, 10.0 mL of 7% (w/v) sodium carbonate (Na2CO3) solution was added to neutralize the reaction, and the resulting mixture was incubated for 90 minutes at 25 ± 2 °C in the dark to prevent photodegradation.

The absorbance of each sample was measured against a reagent blank at 750 nm using a UV–Visible spectrophotometer (Model UV-1800, Shimadzu, Japan). The calibration curve was prepared using gallic acid, and the total antioxidant content of each sample was expressed as milligrams of gallic acid equivalent per gram of extract (mg GAE/g), calculated from the linear regression equation obtained from the standard curve. All determinations were carried out in triplicate, and results were presented as mean ± standard deviation.

2.3. DETERMINATION OF TOTAL FLAVONOID CONTENT

2.3.1. Determination of total flavonoid content

The total flavonoid content (TFC) of the fruit extracts was determined using the aluminum chloride colorimetric method as described by Bilal *et al.* [20] with slight modification. Rutin was used as the standard reference compound for calibration.

A calibration curve was constructed using rutin standard solutions of 0, 10, 20, 30, 40, and 50 mg/L. Briefly, 1.0 mL of each fruit extract or standard solution was mixed with 0.5 mL of 5% (w/v) sodium nitrite (NaNO2) in clean test tubes and allowed to stand for 5 minutes at room temperature. Thereafter, 0.5 mL of 10% (w/v) aluminum chloride (AlCl3) solution was added to each mixture, vortexed, and allowed to react for another 5 minutes. Following this, 4.0 mL of 4% (w/v) sodium hydroxide (NaOH) was added, and the reaction mixture was thoroughly mixed and allowed to stand for 15 minutes for color development.

The absorbance of each solution was measured at 510 nm using a UV–Visible spectrophotometer (Shimadzu UV-1800, Japan) against a reagent blank. The total flavonoid content was calculated from the rutin calibration curve and expressed as milligrams of rutin equivalent per gram of extract (mg RE/g). All measurements were performed in triplicate, and results were reported as mean ± standard deviation (n = 3).

2.4. EXTRACTION AND DETERMINATION OF VITAMIN C.

The ascorbic acid (vitamin C) content of each fruit sample was determined by titrimetric analysis using 2,6-dichlorophenol indophenol (DCPIP) as the oxidizing agent, following the AOAC (2019) method [16, 21].

Approximately 10.0 g of the fresh edible portion of each fruit was ground using a clean porcelain mortar and pestle in the presence of 2.0 g of acid-washed sand to aid cell wall disruption. The homogenization was continued until a fine paste was obtained. The ascorbic acid in the sample was extracted by adding 5.0 mL of 2% (v/v) hydrochloric acid (HCl) and filtering through a small pad of cotton wool into a 100 mL volumetric flask. The extraction was repeated three additional times with fresh portions of 2% HCl to ensure quantitative recovery, and the combined filtrates were made up to the 100 mL mark with distilled water.

An aliquot of 10.0 mL of the extract was titrated against standardized 0.001 M 2,6-dichlorophenol indophenol (DCPIP) solution until a faint pink coloration persisted for 30 seconds, indicating the endpoint. A blank titration was also performed under identical conditions using 2% HCl in place of the extract.

The vitamin C content was calculated using the expression:

$$\text{Vitamin C (mg/100 g)} = \frac{T \times C \times V_1 \times 100}{V_2 \times W},$$

where T = volume (mL) of DCPIP used for titration of the extract, C = concentration (mg/mL) of standard ascorbic acid equivalent to 1 mL of DCPIP, V1 = total volume of extract (mL), V2 = aliquot volume titrated (mL), W = weight (g) of sample analyzed.

All determinations were carried out in triplicate, and the results were expressed as mg of ascorbic acid per 100 g of fresh sample (mg/100 g).

2.5. DETERMINATION OF TOTAL REDUCING PROPERTIES

The total reducing power of each fruit extract was determined according to the method described by Oyaizu (1986) with slight modification [22]. This method is based on the reduction of Fe^{3+} to Fe^{2+} by antioxidant compounds in the sample.

Briefly, 2.5 mL of the methanolic extract of each fruit sample was mixed with 2.5 mL of 0.2 M sodium phosphate buffer (pH 6.6) and 2.5 mL of 1% (w/v) potassium ferricyanide [$K_3Fe(CN)_6$]. The mixture was incubated at 50 ± 2 °C for 20 minutes to allow reduction to occur. After incubation, 2.5 mL of 10% (w/v) trichloroacetic acid (TCA) was added to terminate the reaction, and the mixture was centrifuged at 1000 rpm for 10 minutes to separate the supernatant.

An aliquot of 2.5 mL of the resulting supernatant was combined with 2.5 mL of distilled water and 0.5 mL of 0.1% (w/v) ferric chloride (FeCl3) solution. The absorbance of the reaction mixture was measured at 700 nm using a UV–Visible spectrophotometer (Shimadzu UV-1800, Japan) against a reagent blank.

Ascorbic acid was used as the reference standard, and a calibration curve was prepared using ascorbic acid solutions of varying concentrations. The reducing power of each fruit extract was expressed as milligrams of ascorbic acid equivalent per gram of extract (mg AAE/g). All measurements were conducted in triplicate, and the results were reported as mean ± standard deviation (n = 3).

3. RESULT AND DISCUSSION

Results of triplicate determinations of vitamin C, total flavonoids, total antioxidant, and total reducing properties of the five locally consumed fruits *Anacardium occidentale* (cashew), *Chrysophyllum albidum* (star apple), *Carica papaya* (pawpaw), *Solanum melongena* (garden egg), and *Citrullus lanatus* (watermelon) are summarized in Table 1. All data are presented as mean ± standard deviation (n = 3). The spectrophotometric and titrimetric results reveal substantial variation among the fruits, reflecting differences in phytochemical composition and antioxidant capacity.

3.1. VITAMIN C CONTENT

Pawpaw recorded the highest vitamin C concentration (98.50 ± 0.01 mg/100 g), followed by cashew (82.98 ± 0.02 mg/100 g), while garden egg showed the least value (44.07 ± 0.04 mg/100 g). These findings align with recent reports by Gopalraaj *et al.* [23] and Michael *et al.* [24] on tropical fruits with high ascorbic acid content. Vitamin C, a water-soluble antioxidant, plays an essential role in the regeneration of other antioxidants, especially α-tocopherol (vitamin E), and protects biological membranes against lipid peroxidation [19, 25–27].

Dietary intake of vitamin C-rich fruits has been correlated with decreased oxidative stress, improved collagen synthesis, and enhanced immune function [28]. The results suggest that regular consumption of pawpaw and cashew could contribute significantly to mitigating oxidative stress-associated disorders such as diabetes, cardiovascular diseases, and atherosclerosis, consistent with the findings of Esquivel *et al.* [29].

3.2. TOTAL FLAVONOID CONTENT

Pawpaw exhibited the highest flavonoid content (103.11 ± 0.01 mg/100 g), followed by star apple (71.03 ± 0.07 mg/100 g), while watermelon had the lowest (29.59 ± 0.11 mg/100 g). Flavonoids are potent hydrogen donors and metal chelators, contributing to their capacity to neutralize reactive oxygen species [12, 13, 28, 30, 31]. These compounds modulate cellular signaling pathways associated with inflammation, lipid oxidation, and carcinogenesis.

A strong positive correlation (r = 0.87) was observed between total flavonoid content and reducing power, suggesting that flavonoids significantly influence the electron-donating ability of these fruit extracts. The observed trends are consistent with those reported by Kumar *et al.* [32] for *Carica papaya* and Makinde *et al.* [33] for *Chrysophyllum albidum*, emphasizing the role of flavonoid diversity in determining antioxidant efficiency.

3.3. TOTAL ANTIOXIDANT CAPACITY

Pawpaw again demonstrated the highest total antioxidant capacity (109.17 ± 0.04 mg/100 g), followed by garden egg (52.08 ± 0.07 mg/100 g) and cashew (32.18 ± 0.05 mg/100 g). The antioxidant potential of fruits is largely attributed to synergistic interactions among phenolics, vitamins, and carotenoids [12, 13, 28, 30, 31]. The significant variations observed indicate differences in phytochemical density and pigment concentration across fruit types.

These findings confirm that pawpaw and garden egg are promising dietary sources of antioxidants capable of scavenging free radicals and inhibiting oxidative chain reactions. Similar trends were reported in studies by Nwozo *et al.* [34] and Aluko *et al.* [35], who identified tropical fruits as effective modulators of oxidative biomarkers. The observed antioxidant patterns (watermelon < star apple < cashew < garden egg < pawpaw) reveal

Table 1. Total antioxidant (phenols), total flavonoids, total reducing properties and vitamin C content in the fruit samples

Sample	Vitamin C (mg/100 g)	Total Flavonoid (mg/100 g)	Total Antioxidant (mg/100 g)	Total Reducing properties (mg/100 g)
Cashew (Anacardium occidentale)	82.98 ± 0.02	39.43 ± 0.09	32.18 ± 0.05	31.33 ± 0.09
Star apple (Chrysophyllum albidum)	47.26 ± 0.06	71.03 ± 0.07	30.92 ± 0.03	48.57 ± 0.06
Pawpaw (Carica papaya)	98.50 ± 0.01	103.11 ± 0.01	109.17 ± 0.04	63.23 ± 0.07
Garden egg (Solanum melongena)	44.07 ± 0.04	36.6 ± 0.03	52.08 ± 0.07	40.76 ± 0.02
Watermelon (Citrulus lanatus)	52.57 ± 0.08	29.59 ± 0.11	24.75 ± 0.02	49.43 ± 0.08

the nutritional hierarchy of these fruits in mitigating oxidative stress-induced cellular damage.

3.4. TOTAL REDUCING PROPERTIES

Reducing power reflects the ability of bioactive compounds to donate electrons to free radicals, thereby terminating oxidation reactions [36–38]. In this study, pawpaw exhibited the highest reducing property (63.23 ± 0.07 mg/100 g), followed by watermelon (49.43 ± 0.08 mg/100 g), and star apple (48.57 ± 0.06 mg/100 g). Cashew showed the lowest (31.33 ± 0.09 mg/100 g).

The results demonstrate a moderate correlation (r = 0.76) between total reducing power and total flavonoid content, indicating that phenolics and flavonoids collectively contribute to the electron-transfer mechanisms. The high reducing potential of pawpaw suggests the presence of saponins, alkaloids, and insulin-like peptides that enhance ferric ion reduction, consistent with Olise *et al*. [39]. This property may also explain the reported cholesterol-lowering and antidiabetic effects of these fruits [18, 40, 41].

Overall, the fruits displayed strong antioxidant potential with pawpaw leading in all evaluated indices, indicating its dominance as a nutraceutical candidate. Regular consumption of these fruits could contribute to the reduction of oxidative stress-mediated diseases, promote cardiovascular health, and support metabolic balance.

3.5. COMPARATIVE ASSESSMENT AND HEALTH IMPLICATIONS

The collective findings establish a clear biochemical relationship among vitamin C, flavonoid, antioxidant capacity, and reducing power. Fruits with higher vitamin C and flavonoid content exhibited stronger antioxidant and reducing abilities. This interplay highlights the synergistic mechanism through which multiple antioxidants act to protect biomolecules against oxidative degradation.

From a nutritional perspective, the study reinforces the significance of incorporating diverse locally available fruits into daily diets to combat non-communicable diseases. Pawpaw, star apple, and cashew in particular, represent potent functional foods for developing nutraceutical formulations targeting oxidative stress-related disorders. These findings are consistent with earlier African-based studies by Ekute *et al*. [42], Nwozo *et al*. [34] and Kubola *et al*. [43], further affirming the role of indigenous fruits in sustainable health promotion.

4. CONCLUSION

The findings of this study demonstrate that locally consumed cashew, star apple, pawpaw, garden egg, and watermelon fruits contain significant levels of vitamin C, flavonoids, total antioxidants, and reducing compounds, each exhibiting varying degrees of biological activity. These bioactive compounds, both phenolic and non-phenolic, contribute substantially to the antioxidant capacity of the fruits, supporting their role in mitigating oxidative stress and associated pathologies such as cardiovascular diseases, metabolic disorders, and age-related cellular dysfunction. Regular consumption of these fruits can enhance nutritional status, compensate for micronutrient deficiencies, and support overall human health and longevity. The observed differences in antioxidant profiles among the fruits highlight the importance of dietary diversity to maximize health benefits.

DATA AVAILABILITY

We do not have any research data outside the submitted manuscript file.

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