



# **Comparison of Some *In-vitro* Antioxidant Properties of *Cola acuminata* and *Cola nitida* Fruit Testas**

**Ogunsowo A. O. <sup>a\*</sup>, Odeyemi E. F. <sup>a</sup>, Akinola C. O. <sup>a</sup>,  
Olorundare B. O. <sup>a</sup> and Jayeola C. O. <sup>a</sup>**

<sup>a</sup> Department of Value Addition Research, Cocoa Research Institute of Nigeria, PMB 5244, Idi-Ayunre, Ibadan, Nigeria.

## **Authors' contributions**

This work was carried out in collaboration among all authors. Author OAO conceptualization, research design, statistical analysis, writing of the first draft of manuscript and funding of manuscript.

Author OEF chemical analysis, proof reading, editing and funding of the manuscript.

Author ACO Sample preparation, Chemical analysis, proof reading, editing and funding of the manuscript. Author OBO Literature search, proof reading, editing and funding of manuscript.

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## **ABSTRACT**

Testas of *Cola* fruit are usually considered as agricultural waste by many farmers as their focus is always on the seed because of its economic importance. This study therefore aimed at evaluating and comparing the antioxidant potentials of *C. acuminata* and *C. nitida* fruit testas. The methanol extract of the fruit testas of *C. acuminata* and *C. nitida* were evaluated and compared for their antioxidant properties such as: their scavenging abilities on hydroxyl radicals, ABTS (2, 2-Azino-bis-3-ethylbenzothiazoline-6-sulphonic Acid), DPPH (2, 2-diphenyl-2-picrylhydrazyl) and nitric oxide. Also their ferric reducing ability and total antioxidant were investigated. In all the antioxidant

\*Corresponding author: E-mail: [tobiachiever07@yahoo.com](mailto:tobiachiever07@yahoo.com);

parameters assayed, the fruit testas of *C. acuminata* and *C. nitida* compared favorably well with the standard (Butylated Hydroxytoluene) as they both showed positive correlation with the standard. The antioxidant ability of the methanol extract of *C. nitida* was significantly lower compared with that of *C. acuminata* in all the parameters tested. This can be attributed to the hydrogen atom donating potentials of the testas which can be as a result presence of vital secondary metabolites in therapeutic mopping up of free radicals in form of reactive oxygen species (ROS) and reactive nitrogen species (RNS).

**Keywords:** Antioxidants; hydroxyl radicals; DPPH; testas; cola acuminata; Cola nitida.

## 1. INTRODUCTION

“Many health related problems such as pathological conditions which present cardiovascular disease, cancer, neurological disorder, diabetes and aging have been attributed to oxidative stress. Reactive oxygen species (ROS) and reactive nitrogen species (RNS) are the major free radicals causing harm to the bio-system as they are directly or indirectly responsible for several of these degenerative ailments in human” [1]. Diseases, such as diabetes are responsible for the generation of reactive oxygen species which is as a result of the complications developed such as neuropathy, retinopathy, cardiovascular disease. This may result in cell damage through oxidative stress [1,2].

Blocking the process of oxidative stress requires the engagement of antioxidants which are well-known for their activity in neutralizing the effect of the presence of free radicals in the bio-system. This is achieved by the interruption of the chain reactions where free radicals change other less-harmful molecules to free radicals like themselves [3]. Antioxidant enzymes like superoxide dismutase, catalase, glutathione peroxidase and some non-enzymatic defense molecule like: ascorbic acid, carotenoids glutathione are known to be responsible for protection of the bio-system against cell damage from free radicals by neutralizing ROS and when their functions are impaired, it results in disruption of cell metabolism, cell adaptivity for survival and subsequently leading to cell death [4]. Highly reactive oxygen and nitrogen species damages human health by breaking the bonds in DNA molecules hence, altering the cell's genetic apparatus and subsequently resulting in proliferation of cancerous cells.

In recent times, many plant wastes from agricultural processes are now found to be of economic importance. For instance, the kolanut husk is proven to be good raw material for the

formulation of animal feeds as it has proven not to be detrimental to health of poultry birds [5]. Many plant products are natural source of antioxidants at varying quantities, examples of which include: phenolics, flavonoids, gallic acid e.t.c. [6,7].

*Cola* which has its origin from West Africa, is from the family sterculiaceae and the fruit has a shape like capsule, fleshy with irregular-shaped pink, red or white seeds. The seeds may turn brown when dried [8]. *Cola* is consumed culturally both by individuals or group settings and often for ceremonies such as weddings, funerals and entertainment of tribal chiefs in many parts of Western and sub-Saharan Africa precisely North and Eastern Nigeria, Ivory Coast, Sierra Leone [8,9]. In nutrition, the seed has been used as soft drink additives while in ethnomedicine, the seed is used in managing digestive impairment, food poisoning and even sometimes asthma [10,11].

For several decades the seeds of *Cola* have been the center of attraction in *Cola* fruit because of its wide usage and economic value. There is need to explore other part of the fruit which most times have been regarded as waste in the process of post-harvest handlings. Hence, this study's objective is to determine and compare the antioxidant properties of the fresh *C. acuminata* and *C. nitida* fruit testas.

## 2. METHODS

### 2.1 Collection and Preparation

The pods of *C. acuminata* and *C. nitida* fruits were opened after which the seeds were removed, and then washed with distilled water to remove unwanted particles. The seeds were soaked in water for few days then the testas were removed and air-dried at room temperature under the shade to avoid loss of bioactive components through irradiation. The dried testas were pulverized to fine powder using high speed

blender and finally extracted using methanol as solvent. 10g of the pulverized testa was mixed with 100ml of methanol at room temperature for 24hours after which the supernatant was removed. The residue was re-extracted under the same conditions until the solvent became colorless. The supernatant was then filtered through whatman No. 1 filter paper. The methanol was removed from the filtrate using a rotary evaporator at 40 °C. The methanolic extract was dried and stored in the refrigerator for further analysis.

## 2.2 Determination of 2, 2-Diphenyl-2-Picrylhydrazyl Scavenging Ability

The determination of DPPH (2, 2-diphenyl-2-picrylhydrazyl) radical scavenging activities was evaluated based on the method described by Singh *et al.* [12]. Methanol extracts of the *Cola testas* (1ml) of the different concentrations (5 - 1000µg/ml) made by reconstituting in respective solvents were added to DPPH solution (5ml, 0.1mM) in methanol and mixed. After 20 minutes of reaction at 25°C, the absorbance was measured at 517nm against a blank (methanol) in a UV-Vis spectrophotometer. Methanolic DPPH solution (5ml) without antioxidant was used as control. The DPPH scavenging activity of the extract was expressed as IC<sub>50</sub> (inhibitory concentration), that is, the concentration of the extract at which DPPH radicals were scavenged by 50%. Butyl hydroxy toluene (BHT) was used as standard antioxidant.

The percentage quenching of DPPH was calculated as follows.

$$\text{DPPH Quenching Capacity (\%)} = \frac{(\text{Abs}_{\text{control}}) - (\text{Abs}_{\text{sample}})}{(\text{Abs}_{\text{control}})} \times 100$$

Where:

Abs<sub>sample</sub> is the absorbance of the sample (extract and standard antioxidant) and Abs<sub>control</sub> is DPPH solution without the added extract.

## 2.3 Determination of Scavenging Capacity on Nitric Oxide Radical

“Nitric oxide (NO) generated from sodium nitroprusside (SNP) in aqueous solution at physiological pH was estimated by the use of the Griess reaction” [13]. The reaction mixture (3ml) containing SNP (10mM, 2ml), phosphate buffer

saline (0.5ml, pH 7.4), and the extracts (0.5ml) at different concentrations (5 - 1000µg/ml) were incubated at 25°C for 150min. After incubation, 0.5mL of the incubated solution containing nitrite was pipetted and mixed with 1ml of sulfanilic acid reagent (0.33% in 20% glacial acetic acid) and allowed to stand for 5 min for completing diazotization. Then, 1ml of N-(1-naphthyl) ethylenediamine dihydrochloride was added, mixed, and allowed to stand at 25°C for 30 min. The absorbance of pink colored chromophore formed during diazotization was measured at 540nm. The NO scavenging activity of the extract was expressed as IC<sub>50</sub> (inhibitory concentration), that is, the concentration of the extract at which NO radicals were quenched by 50%. Butyl hydroxy toluene (BHT) was used for comparison.

$$\text{Nitric Oxide Scavenging Capacity (\%)} = \frac{(\text{Abs}_{\text{control}}) - (\text{Abs}_{\text{sample}})}{(\text{Abs}_{\text{control}})} \times 100$$

Where:

Abs sample is absorbance of the sample and Abs control is absorbance of control.

## 2.4 Determination of Ferric Reducing Ability

Ferric reducing capacity was determined according to Oyaizu [14]. From the solution (1000 µgml<sup>-1</sup>) of the *Cola testas* extract, 0.5ml portion was mixed with 2.5ml of sodium phosphate buffer (0.2 M, pH6.6) and 2.5mL of potassium ferricyanide [K<sub>3</sub>Fe<sub>3</sub>(CN)<sub>6</sub>] (1%) in test tubes. The resulting solution was mixed and incubated at 50°C for 20 min. Then, 2.5ml of trichloroacetic acid (TCA) (10%, w/v) was added to all tubes and the solutions were centrifuged at 3000 × g for 10 min. The aqueous solution of FeCl<sub>3</sub> (1%, 1 ml) was diluted by adding deionized water (5 ml). To this solution, the upper layer of the centrifuged solution (5 ml) was mixed and incubated at 35°C for 10 min. Absorbance of the developed color was measured at 700nm. BHT was used as standard. Reducing capacity of the *Cola testas* extracts towards Fe<sup>3+</sup> were expressed as concentration of Fe<sup>2+</sup> in mmol Fe<sup>2+</sup>/g.

## 2.5 Determination of Hydroxyl Radical Scavenging Ability

The hydroxyl radical scavenging assay was performed by the method described by Klein *et al.* [15]. “The testas methanolic extracts and BHT were dissolved separately in DMSO and water. 1

ml of each extracts with various concentrations was mixed with 1 ml of iron-EDTA solution (0.1% ferrous ammonium sulfate and 0.2% EDTA in a ratio of 1:1). After mixing, 0.5ml of 0.02% EDTA solution and 1ml of DMSO were added". [15]

"The reaction was initiated by adding BHT (0.2%) and incubated at 90°C in a water bath for 20 min. Then, 2ml of 15% TCA was added to the termination of the reaction. 2ml of Nash reagent (ammonium acetate (75g), 3ml of glacial acetic acid, and 2 ml of acetylacetone were mixed, and volume was made up to 1L with distilled water) was added and kept at room temperature for 20 min. The reaction mixture without the test extracts served as control, and BHT was used as standard. All the experiments were done in triplicates. A UV-VIS spectrophotometer measured the absorbance of the reaction mixture at 412 nm against a blank solution. The percentage inhibition was calculated from the standard and the IC<sub>50</sub> value was determined" [15].

## 2.6 Determination of 2, 2-Azino-Bis-3-Ethylbenzothiazoline-6 Sulphonic Acid (ABTS) Scavenging Ability

The ABTS radical scavenging ability of *Cola acuminata* and *Cola nitida* fruit testas extracts were determined by method used by Zhou *et al.* [16]. A solution of ABTS radical cation was prepared by reacting 7mM ABTS with 2.45 mM potassium persulfate (K<sub>2</sub>S<sub>2</sub>O<sub>8</sub>) at room temperature in the dark for 16 hours. The mixture was then diluted with deionized water to obtain an absorbance of 0.700 ± 0.005 at wavelength of 734nm. The sample solution (100µl) at a range of concentrations was mixed with the ABTS<sup>+</sup> solution (100µl) in 96-well plates. After incubation at 30 °C for 30 min in the dark, the absorbance at wavelength of 734 nm was immediately recorded. BHT was used as control. The activity of ABTS<sup>+</sup> radical scavenging was calculated.

## 2.7 Determination of Total Antioxidant Capacity

The total antioxidant capacities of the testas were determined using the thiocyanate method [17]. Briefly, 10mg of the methanolic extract of the *Cola acuminata* and *Cola nitida* fruit testas were dissolved in 10ml ethanol. Then, 100 or 250µg/ml of each testas extract or a standard sample in 2.5 ml of potassium phosphate buffer (0.04 M, pH 7.0) was added to 2.5ml of linoleic

acid emulsion in potassium phosphate buffer (0.04 M, pH 7.0). Alternatively, a 5ml control solution was prepared consisting of 2.5ml linoleic acid emulsion and 2.5ml potassium phosphate buffer (0.04 M, pH 7.0). Each solution was incubated at 37 °C in a glass flask in the dark. After reaction with FeCl<sub>2</sub> and thiocyanate, the peroxide values were determined at 3 minutes intervals by reading the absorbance at 500nm in a spectrophotometer. During the linoleic acid oxidation, peroxides form and oxidize Fe<sup>2+</sup> to Fe<sup>3+</sup>. The Fe<sup>3+</sup> ions form a complex with SCN<sup>-</sup> which has a maximum absorbance at 500nm. Therefore high absorbance indicates high linoleic acid oxidation. The solutions without extract were used as blanks. All antioxidant activity data were reported as the average of triplicate analyses. The inhibition of lipid peroxidation in % was calculated by following equation.

$$\% \text{ Inhibition} = 100 - [(A_1/A_0) \times 100]$$

Where;

A<sub>0</sub> was the absorbance of the control reaction and

A<sub>1</sub> was the absorbance in the presence of the testas extract.

## 2.8 Statistical Analysis

All the experimental results were expressed using Graph Pad Prism 9.4.1 as mean ± SEM of three replicates. Data were evaluated using one way variance analysis. *P* values < 0.05 were regarded as significantly different.

## 3. RESULTS AND DISCUSSION

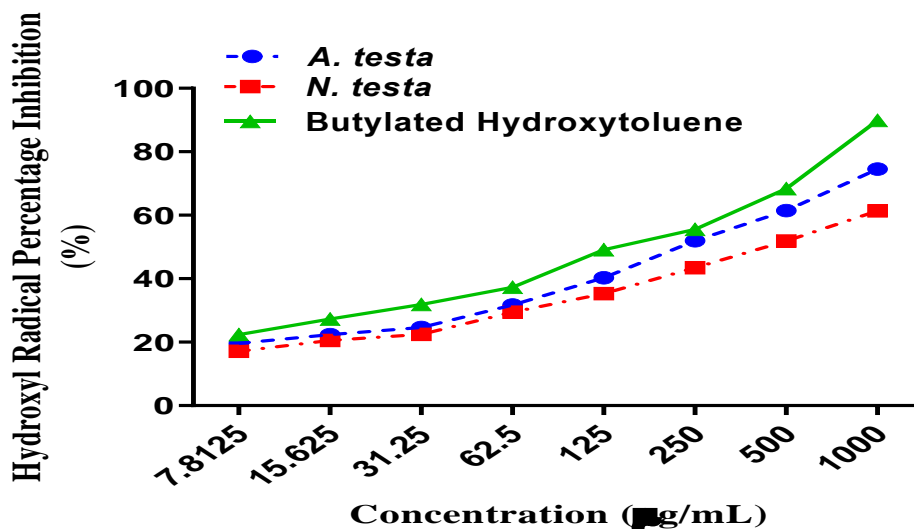
Antioxidant parameters; *in-vitro* inhibitory capacity of the testas of *C. acuminata* and *C. nitida* fruits on Hydroxyl Radical (Fig. 1), ABTS (2,2'-azino-bis 3-ethylbenzothiazoline-6-sulfonic acid) (Fig. 2), DPPH (2, 2-diphenyl-2-picrylhydrazyl) (Fig. 3) and Nitric Oxide (Fig. 4) investigated in this study were found to have a correlating progression with that of standard, Butylated Hydroxytoluene (a common antioxidant utilized in industries) likewise their ferric reducing (Fig. 5) and total antioxidant (Fig. 6) capacities.

The scavenging abilities of *Cola acuminata* fruit testas in percentages on hydroxyl radical (19.60 ± 0.10, 22.41 ± 0.25, 24.60 ± 0.05, 31.74 ± 0.11, 40.25 ± 0.29, 51.95 ± 0.05, 61.45 ± 0.91 and 74.57 ± 0.05); ABTS (39.50 ± 0.18, 45.37 ± 0.16, 51.61 ± 2.08, 55.75 ± 0.21, 62.77 ± 1.99, 68.12 ± 0.15, 74.23 ± 0.12 and 80.30 ± 0.15); DPPH

(21.73 ± 0.17, 28.25 ± 0.19, 34.49 ± 0.12, 42.13 ± 0.13, 49.69 ± 0.04, 56.36 ± 0.16, 68.11 ± 0.11 and 75.50 ± 0.13); Nitric Oxide (25.46 ± 0.23, 31.51 ± 0.11, 38.32 ± 0.10, 46.35 ± 0.17, 50.57 ± 0.24, 55.29 ± 0.10, 60.08 ± 0.17 and 78.37 ± 0.21) at concentrations 7.81, 15.63, 31.25, 62.50, 125.00, 250.00, 500.00 and 1000.00 µg/ml respectively were significantly higher (P<0.05) compared to that of *Cola nitida* fruit testa on hydroxyl radical (17.13 ± 0.10, 20.54 ± 0.36, 22.46 ± 0.20, 29.49 ± 0.10, 35.31 ± 0.05, 43.49 ± 0.19, 51.84 ± 0.24 and 61.34 ± 5.55); ABTS (32.52 ± 0.03, 36.35 ± 0.19, 39.57 ± 0.16, 43.68 ± 0.03, 47.68 ± 0.24, 50.56 ± 0.21, 59.10 ± 0.10 and 63.82 ± 0.12); DPPH (15.21 ± 0.10, 20.50 ± 0.10, 24.94 ± 0.22, 31.24 ± 0.23, 38.77 ± 0.07, 47.68 ± 0.11, 57.01 ± 0.14 and 66.85 ± 0.20); Nitric Oxide (21.88 ± 0.08, 26.67 ± 0.27, 32.27 ± 0.08, 36.99 ± 0.17, 44.10 ± 0.20, 48.63 ± 0.13, 55.33 ± 0.23 and 60.50 ± 0.74) but not significantly as high (P<0.05) as that of the standard, Butylated Hydroxytoluene, on hydroxyl radical (22.35 ± 0.05, 27.29 ± 0.31, 31.85 ± 0.20, 37.29 ± 0.29, 49.15 ± 0.11, 55.52 ± 0.19, 68.37 ± 0.19 and 89.84 ± 0.29); ABTS (42.73 ± 0.16, 48.49 ± 0.15, 59.34 ± 0.49, 70.23 ± 0.17, 74.60 ± 0.14, 80.13 ± 0.03, 85.01 ± 0.07 and 90.20 ± 0.07); DPPH (25.77 ± 0.14, 34.63 ± 0.04, 41.23 ± 0.14, 47.53 ± 0.07, 56.04 ± 0.14, 62.77 ± 0.04, 77.98 ± 0.29 and 81.87 ± 0.14); Nitric Oxide (32.53 ± 0.17, 39.12 ± 0.10, 47.22 ± 0.30, 55.06 ± 0.10, 63.47 ± 0.20, 68.91 ± 0.10, 74.92 ± 0.14 and 82.84 ± 0.20).

Ferric reducing property (Fig. 5) of *C. acuminata* fruit testa was significantly higher (P<0.05) (0.41 ± 0.00 mmol Fe<sup>2+</sup>/g) than that of *C. nitida* fruit testa (0.17 ± 0.00 mmol Fe<sup>2+</sup>/g) but significantly lower (P<0.05) to that of the standard, Butylated Hydroxytoluene (1.05 ± 0.01 mmol Fe<sup>2+</sup>/g). Also, *C. acuminata* fruit testa's total antioxidant capacity (Fig. 6) was significantly high (P<0.05) (9.07 ± 0.06 mg/100mg) as compared to *C. nitida* fruit testa (7.00 ± 0.08 mg/100mg) and significantly lower (P<0.05) to that of Butylated Hydroxytoluene (11.50 ± 0.14 mg/100mg).

Seeds of both species of *Cola* has been found to contain phytochemicals with antioxidant properties such alkaloids and tannins [18]. Hydroxyl radical is important reactive oxygen specie which can react with some other biomolecules such as polyunsaturated fatty acid units in phospholipids of the cell membrane subsequently leading to cell damage and responsible for lipid peroxidation, protein oxidation and disruption of the DNA [19][20]. The hydroxyl radical scavenging power of these testas significantly increase as concentration increases with the IC<sub>50</sub> of *C. acuminata* testa (124.67 ± 0.96 µg/ml) significantly lower (P<0.05) than that of *C. nitida* (157.63 ± 11.58 µg/ml). The IC<sub>50</sub> of both testas were significantly higher (P<0.05) than that of the standard, butylated hydroxytoluene (109.67 ± 0.52 µg/ml).

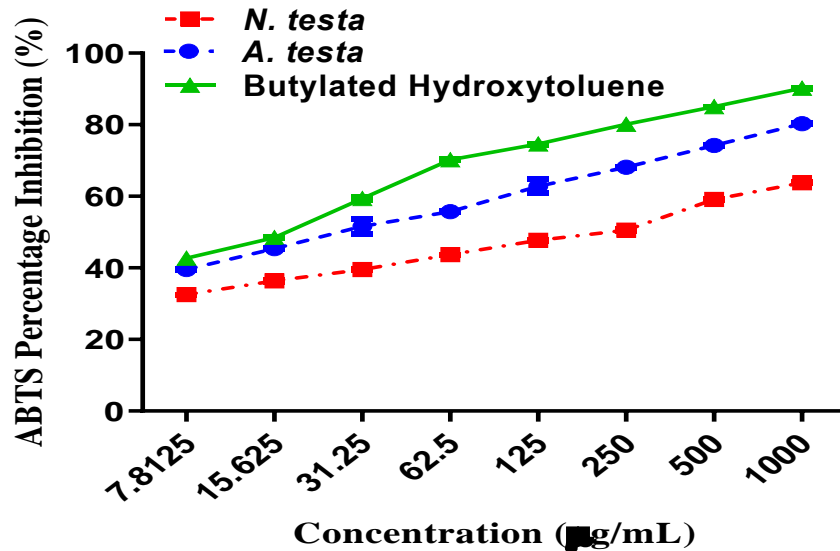


**Fig. 1. In-vitro hydroxyl radical scavenging ability of testas of *cola acuminata* and *cola nitida* fruits**

Values are expressed as mean of three replicates ± Standard Error of Means

Key: *A. testa* = *Cola acuminata* seed testa

*N. testa* = *Cola nitida* seed tetsa

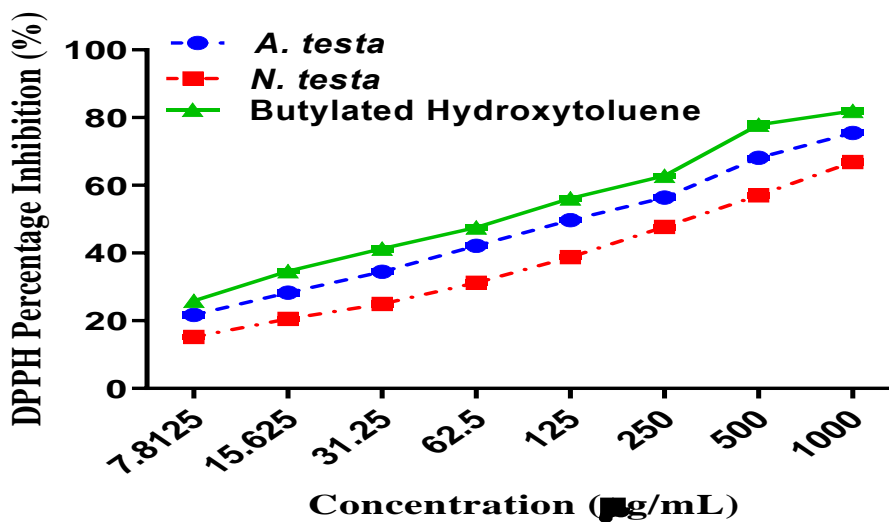


**Fig. 2. ABTS (2,2<sup>1</sup>-azino-bis 3-ethylbenzothiazoline-6-sulfonic acid) Scavenging Ability of testas of *Cola acuminata* and *Cola nitida* Fruits**

Values are expressed as mean of three replicates  $\pm$  Standard Error of Means

Key: A. testa = *Cola acuminata* seed testa

N. testa = *Cola nitida* seed tetsa



**Fig. 3. DPPH (2, 2-diphenyl-2-picrylhydrazyl) scavenging ability of testas of *cola acuminata* and *cola nitida* fruits**

Values are expressed as mean of three replicates  $\pm$  Standard Error of Means

Key: A. testa = *Cola acuminata* seed testa

N. testa = *Cola nitida* seed tetsa

ABTS is commonly known for its use by many food and agricultural research based industries to estimate the antioxidant potentials of foods because the radical cation reacts to most antioxidants such as phenolic, thiol and vitamin C also for determining the antioxidant capacity of

substances such as phenolics, carotenoids e.t.c [21][22][23]. DPPH is one of the most important molecules for the in vitro antioxidant assays. It is known to have hydrogen acceptor capability. The hydrogen atom donating capability of the extracts of the testas was estimated by the decolorization

of methanol solution of DPPH. Nitric oxide on the other hand is important for the physiologic role it plays in the generation of reactive nitrogen species which is known for its cell injury or death causing ability by induction of nitrosative stress [24]. Nitric oxide reacts with superoxide anion radical ( $O_2^{\cdot-}$ ) to produce peroxyntirite anion ( $ONOO^-$ ) a Reactive Nitrogen Species. The

inhibitory effect of the testas of both *C. acuminata* and *C. nitida* on the hydroxyl radical, DPPH, ABTS and Nitric oxide compared favourably well with the results of some of the positive antioxidant properties as reported by Olorunfemi et al. and Sudha et al. [25] (85.73%, 36.71%, 14.25% and 76.12% respectively).

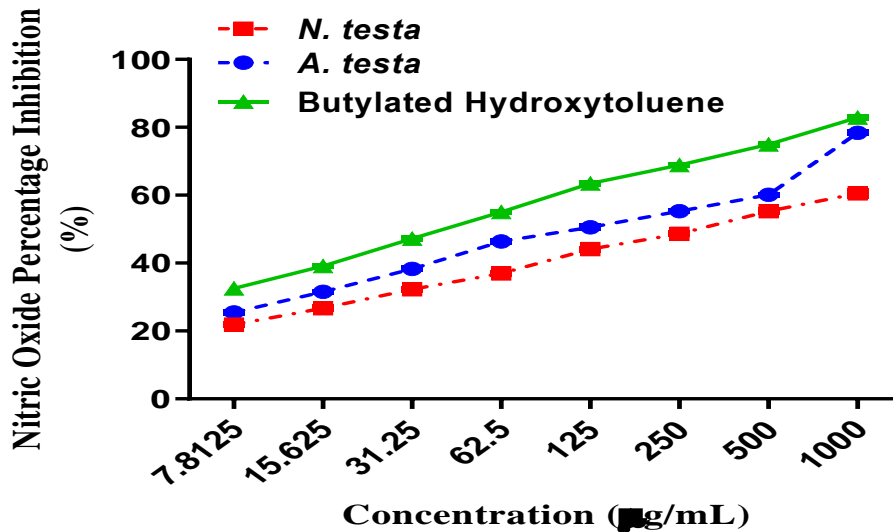


Fig. 4. Nitric oxide scavenging ability of *cola acuminata* and *cola nitida* fruits

Values are expressed as mean of three replicates  $\pm$  S.E.M

Key: *A. testa* = *Cola acuminata* seed testa

*N. testa* = *Cola nitida* seed tetsa

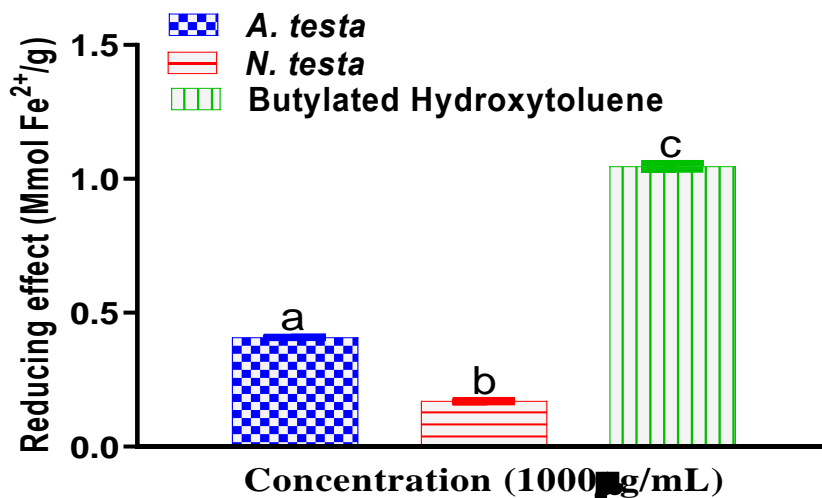
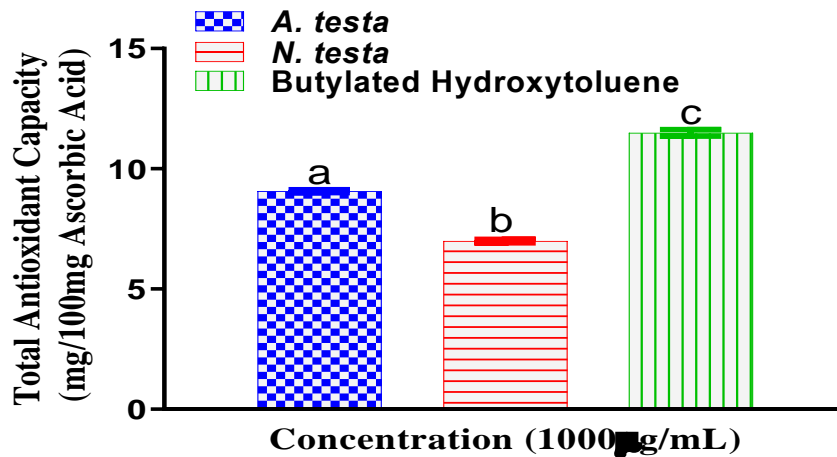


Fig. 5. Ferric reducing ability of testas of *cola acuminata* and *Cola nitida* fruits

Values are expressed as mean of three replicates  $\pm$  S.E.M and bars with different alphabets are significantly different ( $P < 0.05$ ) from each other.

Key: *A. testa* = *Cola acuminata* seed testa

*N. testa* = *Cola nitida* seed tetsa



**Fig. 6. Total antioxidant capacity of testas of *cola acuminata* and *cola nitida* fruits**  
 Values are expressed as mean of three replicates  $\pm$  S.E.M and bars with different alphabets are significantly different ( $P < 0.05$ ) from each other.

Key: A. testa = *Cola acuminata* seed testa  
 N. testa = *Cola nitida* seed tetsa

#### 4. CONCLUSION

Although with antioxidant properties not as high as that of standard, butylated hydroxytoluene, the extracts of *C. acuminata* and *C. nitida* fruit testas showed a positive correlation (with increased concentration) with the standard. The *C. acuminata* fruit testa possess higher antioxidant capabilities than the *C. nitida* fruit testa. This may be attributed to strong hydrogen donating ability and scavenging ability of the testas on free radicals which are important precursors for the generation of reactive oxygen species and reactive nitrogen species. Hence, these testas can serve as potential precursor for discovery of novel drugs in the pharmaceutical industry.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

#### REFERENCES

1. Temesgen S, Sasikumar JM, Egiga MC. Effect of Extraction Solvents on Total

Polyphenolic Content and Antioxidant Capacity of *Syzygium aromaticum* L. Flower Bud from Ethiopia. *Hindawi BioMed Research International*.2022:2022:9. Article ID 4568944. Available:<https://doi.org/10.1155/2022/4568944>

2. Mahmoodnia L, Aghadavod E, Biegrezaei S, Rafieian-Kopaei M. An Update on Diabetic Kidney Disease, Oxidative Stress and Antioxidant Agents. *Journal of Renal Injury Prevention*. 2017;6: 153–157.

3. Fabunmi TB, Arotupin DJ. Antioxidant Properties of Fermented Husk and Testa of Three Species of Kolanut: *Cola acuminata*, *Cola nitida* and *Cola verticillata*. *British Biotechnology Journal*. 2015;8(2):1–13. Article no. BBJ. 18443 ISSN: 2231-2927.

4. Jena AB, Samal RR, Bhol NK, Duttaroy AK. Cellular Red-Ox System in Health and Disease: The Latest Update. *Biomedicine & Pharmacotherapy*.2023;162(2023) 114606. Available:<https://doi.org/10.1016/j.biopha.2023.114606>

5. Fabunmi TB, Arotupin DJ, Adegunloye DV, Orunmuyi M, Odole BS. Effects of Kolanut Husk Formulated Feed at Graded Levels on Growth Performance and Health of Ross Broilers With and Without Enzyme Inclusion. *Acta Scientific Agriculture* 2019; 3(2):105–113.ISSN: 2581–365X.



6. Phuyal N, Jha PK, Raturi PP, Rajbhandary S. Total Phenolic, Flavonoid Contents and Antioxidant Activities of Fruit, Seed and Bark Extracts of *Zanthoxylum armatum* DC. Scientific World Journal. 2020; 2020:8780704. Doi. 10.1155/2020/8780704. PMID: 32256249; PMCID: PMC7102453
7. Sun W, Shahrajabia MH. Therapeutic Potential of Phenolic Compounds in Medicinal Plants-Natural Health Products for Human Health. *Molecules*. 2023;28(4): 1845. Available:https://doi.org/10.3390/molecules 28041845
8. Lowe HIC, Watson CT, Badal S, Peart P, Toyang NJ, Bryant J. Promising efficacy of the *Cola acuminata* Plant: A Mini Review. *Advances in Biological Chemistry*. 2014;4(4):240–245. Available <http://www.scirp.org/journal/abc> Available <http://dx.doi.org/10.4236/abc.2014.44029>
9. Sonibare MA, Soladoye MO, Esan OO. Sonibare OO. Phytochemical and Antimicrobial Studies of four Species *Cola* Schott & Ednl. (Sterculiaceae). *Afr J Tradit Complement Altern Med*. 2009;6(4):518-525. DOI: 10.4314/ajtcam.v6i4.57182 PMID: 20606771; PMCID: PMC2816472
10. Warner M. Herbal Plants of Jamaica. Macmillan Caribbean, Thailand. 2007;94 – 95
11. Odebunmi E, Oluwaniyi O, Awolola G. Proximate and Nutritional Composition of Kola Nut (*Cola nitida*), Bitter Cola (*Garcinia cola*) and Alligator Pepper (*Afromomum melegueta*). *African Journal of Biotechnology*. 2009;8:308–310.
12. Singh RP, Chidambara-Murthy KN, Jayaprakash GK. Studies on the antioxidant activity of pomegranate (*Punicagranatum*) peel and seed extracts using in vitro models. *J Agric Food Chem*. 2002;50(1):81– 6. Doi: 10.1021/jf010865b. PMID: 11754547
13. Green LC, Wagner DA, Glogowski J, Skipper PL, Wishnok JS, Tannenbaum, SR. Analysis of nitrate, nitrite, and [15N] nitrate in biological fluids. *Anal Biochem*. 1982;126(1):131–8. Doi: 10.1016/0003-2697(82)90118-x. PMID: 7181105
14. Oyaizu M. Studies on products of browning reaction prepared from glucosamine. *Japanese Journal of Nutrition*. 1986;44:307–315. Available:<http://dx.doi.org/10.5264/eiyogakuzashi.44.307>
15. Klein SM, Cohen G, Cederbaum AI. Production of formaldehyde during metabolism of dimethyl sulfoxide by hydroxyl radical generating systems. *Biochemistry*. 1981;20(21):6006-12. DOI: 10.1021/bi00524a013. PMID: 6272833
16. Zhou Y, Li L, Sun L, Zhou L, Xu Y. In comparison with vitamin C and butylated hydroxytoluene, the antioxidant capacity of aqueous extracts from buds and flowers of *Lonicera japonica* Thumb. *J. Tradit Chin Med*. 2018;15,38(3):373–379. DOI:10.1016/S0254-6272(18)30627-7 ISSN 0255 – 2922
17. Mitsuda H, Yuasumoto K, Iwami K. Antioxidant Action of Indole Compounds during the Autoxidation of Linoleic Acid. *JJSFN*. 1966;19(3):210–214. DOI: 10.4327/jsnfs1949.19.210
18. Alam MN, Bristi NJ. Rafiquzzaman M. Review on in vivo and in vitro methods evaluation of antioxidant activity. *Saudi Pharm J*. 2013;21(2):143-52. DOI: 10.1016/j.sps.2012.05.002. PMID: 24936134; PMCID: PMC4052538.
19. Fleming AM, Burrows CJ. On the irrelevancy of hydroxyl radical to DNA damage from oxidative stress and implications for epigenetics. *Chem Soc Rev*. 2020;49(18):6524–6528. DOI: 1039/d0cs00579g. PMID: 32785348; PMCID: PMC7522918.
20. Huang D, Ou B, Prior RL. The chemistry behind antioxidant capacity assays, *J. Agric. Food Chem*. 2005;53(6):1841–56. DOI: 10.1021/jf030723c. PMID: 15769103.
21. Walker RB, Everette JD. Comparative reaction rates of various antioxidants with ABTS radical cation, *J. Agric. Food Chem*. 2009;57(4):1156–61. DOI: 10.1021/jf8026765. PMID: 19199590.
22. Bibi Sadeer N, Montesano D, Albrizio S, Zengin G, Mohomoodally MF. The Versatility of Antioxidant Assays in Food Science and Safety-Chemistry, Applications, Strengths and Limitations. *Antioxidants (Basel)*. 2020;9(8):709. Doi: 10.3390/antiox9080709. PMID: 32764410; PMCID: PMC7464350.

23. Martinez MC, Andriantsitohaina R. Reactive Nitrogen Species: Molecular Mechanisms and Potential Significance in Health and Disease. *Antioxid Redox Signal*. 2009;11(3):669–702. Doi: 10.1089/ars.2007.1993. PMID: 19014277. Available: <https://doi.org/10.1177/1082013221991256>. ISSN: 2375 – 3935.
24. Olorunfemi AM, Awolu OO, Enujiugha VN. Anti-hypertensive and Antioxidant Potentials of Wheat Substituted with Two Underutilized Seed Flours. *American Journal of Food Science and Nutrition*. 2018;5(1):17–25.
25. Sudha D, Malarkodi R, Gokulakrishnan A, Liyakath Ali AR. Antioxidant and Free Radical Scavenging Activity of Different Extract of Three Varieties of *Carissa carandas* Fruits and Inhibition of Digestive Enzymes Relevant to Type 2 Diabetes Mellitus. *IJPSR*. 2022;13(11): 4466– 4475. DOI: 10.13040/IJPSR.0975-8232.13(11).4466-75

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