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***Research Article***

# Phytochemicals, Mineral Elements and Antioxidants Evaluation of Some Commonly Consumed Desert Fruits

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**ABSTRACT**

The medicinal properties of fruits are closely related to their available phytochemicals, as well as antioxidant capacity. Many of the indigenous fruits have been traditionally used as folk medicine. This study aims to evaluate the phytochemicals, mineral elements, and antioxidant properties of five (5) commonly consumed desert fruits such as *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis*. The phytochemicals, mineral elements, and antioxidants were carried out using standard methods of analysis. The result revealed that phytochemicals such as alkaloids, flavonoids, phenols, tannins, saponins, steroids, terpenoids, and glycosides were present in all five fruits studied with varied compositions. While the mineral elements such as Potassium (K), Magnesium (Mg), Calcium (Ca), Sodium (Na), Iron (Fe), Manganese (Mn), Zinc (Zn), and Copper (Cu) were present indicated that the fruits have substantial mineral elements, however, varied according to the fruits species studied*, Hyphaene thebaica* exhibits the highest elemental content. The DPPH inhibition properties emphasize the diverse antioxidant capabilities of the studied fruits in which *Diospyrosme spiliformis* (DS) emerges as a standout in DPPH inhibition activity, exhibiting robust antioxidant activity, closely followed by *Dialium guineense* (DG). The nitric oxide radical scavenging reveals a concentration-dependent response in the NO radicals scavenging activity for all the fruits and ascorbic acid. The findings conclude that the five desert fruits species revealed different phyto-constituents, mineral elements, Nitric oxide radical scavenging effect, and DPPH inhibition properties suggesting potential medicinal and nutritional properties of the five desert fruits.

**Keywords:** Phytochemicals, Minerals elements, Antioxidants, Desert Fruits, Nutrition

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## INTRODUCTION

Fruits are commonly consumed for their nutrients, and some fruits are used as medicine. The medicinal properties of fruits are closely related to their available phytochemicals, as well as antioxidants. Many of the indigenous fruits have been traditionally used as folk medicine. These fruits contain phytochemical antioxidants that can prevent, treat, and cure various types of diseases (Thilakarathina *et al.,* 2012). Many phytochemicals such as carotenoids, tannic acids, triterpenes, and some flavonoids are free radical scavengers that can contribute to the suppression of oxidative stress and anti-inflammatory effect in the human body (Thilakarathina *et al.,* 2012). Among the 15 indigenous tropical fruits, the flesh of five fruits are not scientifically determined for their medicinal values, except for antioxidant activities. The other fruits have been studied for antimicrobial effects (including fungal) and several protective effects against chronic diseases (Thilakarathina *et al.,* 2012). Among the scientific evidence shown in previous literature, most of the experiments are mainly focused on in vitro and animal models. Limited studies on human intervention trials allow researchers or scientists to study the potential health effects of these underutilized tropical fruits using human models in the future.

The use of medicinal plants in healthcare by people of different culture and races across the globe is as old as the history of man (Egwaikhide *et al.,* 2009). Over 80% of world population, especially in the developing world depends on herbal remedies. Studies have shown that the efficacy of medicinal plants for the treatment of certain disease hinges on the presence of phytochemical substances such as alkaloids, flavonoids, tannins, steroids, saponins, terpenes, glycosides and coumarins (Shagal *et al.,* 2012*,* Igbinosa *et al.,* 2009). Consequently, there is need to provide scientific basis for the use of such plants in traditional medicine. Plants used for traditional medicine contain a wide range of substances that can be used to treat chronic as well as infectious diseases (Duraipandiyan *et al.,* 2006). In many cases the people claim the good benefit of certain natural or herbal products. However, clinical trials are necessary to demonstrate the effectiveness of abioactive compound to verify this traditional claim. Clinical trials directed towards understanding the pharmacokinetics, bioavailability, efficacy, safety and drug interactions of newly developed bioactive compounds and their formulations (extracts) require a careful evaluation. *Hyphaene thebaica, (*Goriba*), Detarium senegalensce (*Taura*), Ziziphus jujuba (*Magarya*), Dialium guineense (*Tsamiyarbiri*) and Diospyros mespiliformis (*Kanya*)* has been used in traditional medicine in many countries including Nigeria, specifically the northern part of Nigeria. It is now taken uncontrolled by children and adults in both rural and urban areas for treatment of various ailments as such screening these fruits for bioactive compounds and medicinal properties as well as nutritional value will be of great importance**.**

## MATERIALS AND METHODS

### Sample Collection and Preparation

The Fresh fruits were collected from Kazaure market, Kazaure Local government, Jigawa state, Nigeria. They were authenticated at Biology Department of Science Laboratory and Technology. The fruits were stored in a dark cool box at $4^{O}C$ and transported to the laboratory for analysis.

### Preparation of Extracts Using Maceration Method of Extraction

Fresh fruits were washed under running tap water, air dried and powdered. About 50g of coarsely powdered fruits materials were weighted and dissolved in 500ml of distilled water. It was shaken vigorously and allowed to stand for 24 hrs. It was then filtered using cheese cloth and followed by Whatman's filter paper No. 1 All the aqueous extracts were then concentrated and evaporated to dryness in vacuum under reduced pressure and stored in sterile glass bottles at room temperature until screened

### Qualitative Phytochemical Evaluation of *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* Aqueous Fruits Extract

The aqueous extracts of the five fruits were weighed and dissolved in 50ml of distilled water separately. The mixture was shaken gently and allowed to dissolve for about five (5) minutes the solution was then subjected to the following qualitative tests.

### Test for Alkaloids

Few drops of 1% HCl were added to the filtrate to which 5 drops of freshly prepared Dragendorrf‟s reagent was added. Formation of a precipitate indicated the presence of alkaloids (Li *et al*., 2021).

**Test for Anthraquinones**

5ml of the filtrate was hydrolysed with diluted Conc. $H_2SO_4$. 1 ml of dilute ammonia was added to it. Rose pink coloration suggested the positive response for anthraquinones (Li *et al*., 2021).

**Test for Polyphenolsa**

Yellow precipitates obtained by the addition of 3 drops of lead acetate solution (5%) to the filtrate indicated the presence of phenolic compounds (Li *et al*., 2021).

**Test for Tannins**

0.5g of the dried powdered sample was boiled in 20 ml of water in a test tube and then filtered. A few drops of 0.1% ferric chloride were added. Formation of brownish green or a blue-black colouration indicated the presence of tannins (Li *et al*., 2021).

**Test for Saponins**

2 g of the powdered sample was boiled in 20 ml of distilled water in a water bath and then filtered. 10 ml of the filtrate was mixed with 5 ml of distilled water and shaken vigorously for a stable persistent froth. The frothing was mixed with 3 drops of olive oil and shaken vigorously*,* formation of emulsion indicates the presence of saponin (Li *et al*., 2021).

**Test for Flavonoids**

5 ml of dilute ammonia solution was added to a portion of the aqueous filtrate of the powdered sample followed by the addition of concentrated $H_2SO_4$. A yellow colouration observed in each filtrate indicated the presence of flavonoids. The yellow colouration disappeared on standing (Li *et al.,* 2021).

**Test for Terpenoids (Salkowski Test)**

5ml of the filtrate was mixed in 2 ml of chloroform*,* 3ml of concentrated $H_2SO_4$ was carefully added to form a layer. A reddish brown colouration of the inter face was formed to show positive results for the presence of terpenoids.

**Test for Cardiac Glycosides (Keller-Killani test)**

5ml of the filtrate was treated with 2 ml of glacial acetic acid containing one drop of ferric chloride solution. This was then treated with 1 ml of concentrated sulphuric acid. A brown ring of the interface indicated a deoxysugar characteristic of cardenolides (Li *et al*., 2021).

**Test for Anthocyanins**

2 ml of aqueous filtrate was added to 2 ml of 2N HCl and ammonia. The appearance of reddish-pink turned blue-violet indicated the presence of anthocyanins (Li *et al*., 2021).

**Test for Phenols**

Ferric Chloride Test**:** Extracts were treated with 3-4 drops of ferric chloride solution. The formation of bluish-black colour indicates the presence of phenols.

**Quantitative Phytochemical Evaluation of *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* Aqueous Fruits Extract**

**Determination of Total Flavonoids**

Total flavonoids content was determined by aluminium chloride method described by (Kumar *et al.,* 2008) with minor modification. 0.5 ml of the sample was mixed with 0.3 ml of 5% sodium nitrite. After 5 min 0.3 ml of 10% aluminum chloride was added. After 6 min, 2.0 ml of 1 M sodium hydroxide was added and the total volume was made up to 5.0 ml with distilled water. The absorbance of the mixture was measured at 510 nm against a reagent blank. Catechol was used as a standard. The flavonoid content was expressed as milligrams of catechol equivalence (CAE) per gram of extract.

**Determination of Alkaloids**

5 g of the sample was weighed into a 250 ml beaker and 200 ml of 10% acetic acid in ethanol was added and covered and allowed to stand for 4hr. This was filtered and the extract was concentrated on a water bath to one-quarter of the original volume. Concentrated ammonium hydroxide was added drop wise to the extract until the precipitation was complete. The whole solution was allowed to settle and the precipitate was collected and washed with dilute ammonium hydroxide and then filtered. The residue was the alkaloid, which was dried and weighed (Li *et al.,* 2021).

**Determination of Tannins**

500 mg of the sample was weighed into a 50 ml plastic bottle. 50 ml of distilled water was added and shaken for 1hr in a mechanical shaker. This was filtered into a 50 ml volumetric flask and made up to the mark. Then 5 ml of the filtrate was pipetted out into a test tube and mixed with 2 ml of 0.1 M $FeCl_3$ in 0.1N HCl

and 0.008 M potassium ferrocyanide. The absorbance was measured at 720 nm within 10min (Li *et al.,* 2021).

**Determination of Saponin**

The samples were ground and 20 g of each were placed into a conical flask and 100cm3 of 20% aqueous ethanol was added. The samples were heated over a hot water bath for 4hr with continuous stirring at about $55^0$C. The mixture was filtered and the residue was re-extracted with another 200 ml of 20% ethanol. The combined extracts were reduced to 40ml over a water bath at about $90^0$C. The concentrate was transferred into a 250 ml separating funnel and 20ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered while the ether layer was discarded. The purification process was repeated. 60 ml of n-butanol was added. The combined n-butanol extracts were washed twice with 10 ml of 5% aqueous sodium chloride. The remaining solution was heated in a water bath. After evaporation, the samples were dried in the oven to a constant weight (Li *et al.,* 2021).

**Determination of Cardiac Glycosides**

A tincture of the sample was prepared by preparing 10% extract in 70% alcohol by shaking 1g of pulverized mint with 10ml 70% alcohol. The mixture was left overnight with occasional shaking for 2hr and then filtered. 10ml of the purified filtrate transferred into a dry stopped Erlynmeyer flask was added to 10ml of baltet's reagent. The blank was prepared at the same time using 10ml of distilled water instead of the purified filtrate and 10ml of Baljet's reagent. They were made to stand for 1hr, for maximum colour development. The solutions were diluted with 20ml of distilled water and mixed. The intensity of the colour obtained was measured at 495nm using a suitable spectrophotometer. The colour was stable for several hours. The difference between experiment and blank (E-B) is equal to the original reading. The percentage total glycoside was calculated using the absorptivity of digitoxin = 170, similarly treated at 495 nm as follows:

% Total cardiac glycoside = (A x 100 / 17) g% Calculated as digitoxin.

Where A = absorbance of the colour at 495nm.

**Determination of Total Phenols by Spectrophotometric Method**

The total phenolic content in various fruits extracts of *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* were assessed by FolinCiocalteau's method (Singleton and Rossi, 1965). To 1.0 ml of the sample, 1.0 ml of FolinCiocalteau's reagent was added. After 3 min, 1.0 ml of saturated $Na_2CO_3$ (~35%) was added to the above mixture and the final volume was made up to 10 ml with distilled water. The tubes were kept in dark for 90 min, after which its absorbance were read at 725 nm against a reagent blank. Gallic acid was used as standard. Results were expressed as milligrams of Gallic Acid Equivalence (GAE) per gram of extract.

**Mineral Elements Evaluation of *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* Aqueous Fruits Extract**

The mineral elements (Na, K, Ca, Mg, Fe, and Zn) were determined by Atomic Absorption Spectrophotometry (AAS). Briefly, about 2 g of the sample of each fruit was dried using a hot oven at 100 °C for 30 minutes. The dried samples were placed on hot plate until smoke-free. Subsequently, a furnace set at 550 °C for 3 hours was used to obtain white ash of the samples. The ash was dissolved in 5 ml of 6 M HCl by warming on a hot plate for 2-3 minutes. The solution obtained was taken to a 50 ml flask followed by the addition of 1 M $HNO_3$. Dry ashing was used to remove organic materials from the solution followed by dissolving the residue in diluted acid. The standard solution of the mineral elements was prepared by dissolving the stock standard in 0.3 N HCl to the desired concentrations. The AAS was calibrated using the standard solution. The solutions were sprayed into the Atomic Absorption Spectrophotometer (AAS) and minerals were quantified by taking the absorbance at a specific wavelength of the elements.

**Antioxidants Evaluation of *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* Aqueous Fruits Extract**

**Determination of DPPH Radical Scavenging Activity:**

DPPH was determined according to Brand-william (1995) A stock solution of 0.1 mM DPPH was prepared in methanol. This stock solution was diluted with methanol to obtain a working solution of 0.02 mM DPPH. Different concentrations of the test sample were prepared by serial dilution. Equal

volumes of the test sample and DPPH solution were mixed, and the mixture was incubated in the dark at room temperature for 30 minutes. The absorbance at 517 nm was measured using a spectrophotometer. The percentage inhibition of DPPH radical was calculated using the formula:

Inhibition(%)=(1−Absorbance of control/Absorbance of sample)×100%

**Determination of Nitric Oxide Radical Scavenging Activity:**

Nitric oxides was determine based on the methods described by Akowuah (2005) Sodium nitroprusside (SNP) solution was prepared by dissolving it in phosphate-buffered saline (PBS) to a final concentration of 10 mM. Different concentrations of the test sample were mixed with SNP solution and incubated at 37°C for 150 minutes. After incubation, Griess reagent (1% sulfanilamide and 0.1% N-1-naphthylethylenediamine dihydrochloride in 5% phosphoric acid) was added to the reaction mixture. The mixture was allowed to stand at room temperature for 10 minutes, and the absorbance at 540 nm was measured using a spectrophotometer. The percentage inhibition of nitric oxide radical was calculated using the formula:

Inhibition (%) = (1 - (Absorbance of sample/Absorbance of control)) × 100.

**RESULTS**

**Qualitative phytochemicals composition Aqueous Fruits extract *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* Aqueous Fruits Extract**

The qualitative phyto-constituents analysis of the aqueous extracts from five different fruits species: *Hyphaene thebaica (HT), Detarium senegalensce (DSN), Ziziphus jujuba (ZJ), Dialium guineense (DG)*, and *Diospyrosme spiliformis* (DS). The focus of this analysis is on various phytochemical parameters including alkaloids, flavonoids, phenols, tannins, saponins, steroids, terpenoids, and glycosides. HT and ZJ extracts showed a high presence (++ and +, respectively) of alkaloids, while DSN, DG, and DS showed varied levels. Overall, there is no significant difference in the alkaloid presence among the fruits species .HT and DS extracts exhibited a high presence of flavonoids (++) and ++, respectively), whereas ZJ, DG, and DS showed moderate to low levels. HT and DSN extracts lacked phenols, while ZJ and DG were moderatly presence. DS extract exhibited a high presence of phenols (+++). Significant variations exist among the fruits species regarding the phenol content. HT and DS extracts revealed moderate (++) amount of tannins, while DSN, ZJ, DG showed varied levels. While for saponins HT and DSN extracts showed moderate presence of saponins (++), while ZJ, DG, and DS showed varied levels. Additionally, HT, DG, and DS extracts exhibited a high presence of steroids (+++), while DSN and ZJ showed moderate levels steroid presence. There was presence of high level of terpenoids in HT while DSN, ZJ, and DG showed moderate levels. HT showed a high presence of glycosides (+++), while DG exhibited moderate presence (++). The qualitative phytochemical analysis reveals notable differences in the presence of various phytochemical constituents among the studied fruits. These differences are indicative of the diverse bioactive compounds present in these fruits, which could have implications for their potential medicinal and nutritional properties.

**Quantitative phytochemicals composition of Aqueous Fruits extract of *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* Aqueous Fruits Extract**

The quantitative phytochemicals composition of some commonly Consumes Aqueous Fruits extract such as *Hyphaene thebaica* (HT), *Detarium senegalensce* (DSN), *Ziziphus jujuba* (ZJ), *Dialium guineense* (DG), and *Diospyrosme spiliformis* (DS) were presented in table 2. The phytochemical parameters examined include Alkaloids, Flavonoids, Phenols, Tannins, Saponins, Steroids, Terpenoids, and Glycosides. HT has the highest alkaloid content (0.97 ± 0.06) followed by DSN and ZJ. However, DS and DG have comparatively lower alkaloid levels. Significant differences (P = 0.001) between the fruit species were observed. DSN exhibits the highest flavonoid content (6.07 ± 0.12). HT, ZJ, DG, and DS have notably lower flavonoid levels. The differences in flavonoid content are highly significant (P = 0.001). The phenols content of DSN, ZJ, DG, and DS were obtained, with DSN having the highest value (0.42 ± 0.03). The differences in phenol content are statistically significant (P = 0.006). While the tannins content of DSN demonstrates the highest values (4.3 ± 0.10).while the ZJ, DG, and DS fruits exhibit significant (P = 0.001). Presence of tannins, though lower than DSN. The fruits of DSN has the highest saponin content (3.37 ± 0.06), followed by HT and ZJ. DG and DS have

comparatively lower saponin levels. The differences in saponin content are statistically significant (P = 0.001). The steroid content of DSN was found to be (3.17 ± 0.12). While the fruits of HT, ZJ, DG, and DS have lower steroid levels with significant difference (P = 0.001) between the five fruits.

DSN has the highest terpenoid content (2.90 ± 0.10). HT, ZJ, DG, and DS exhibit comparatively lower terpenoid levels. The differences in terpenoid content are highly significant (P = 0.001) among the fruits. The glycoside content of DSN was (3.27 ± 0.15), followed by HT and DG. ZJ and DS with significant differences (P = 0.001) exist between the fruits (table 2).

**Table 1: Qualitative phytochemicals composition of *Hyphaene thebaica, Detarium senegalensce, Ziziphus Jujuba, Dialium guineense and Diospyros mespiliformis Aquoeus fruts extract***

| Phytochemicals | *Hyphaene thebaica* (HT), | *Detarium senegalensce* (DSN), | *Ziziphus jujuba* (ZJ), | *Dialium guineense* (DG), | *Diospyrosme spiliformis* (DS). |
|---|---|---|---|---|---|
| Alkaloids | ++ | ++ | ++ | ++ | ++ |
| Flavonoids | +++ | + | + | + | +++ |
| Saponins | ++ | + | + | + | ++ |
| Steroids | +++ | ++ | ++ | +++ | +++ |
| Tannins | ++ | + | + | + | ++ |
| Terpenoids | +++ | + | + | ++ | ++ |
| Glycosides | +++ | + | + | ++ | +++ |
| Phenols | - | - | ++ | ++ | +++ |

**Key:** HT = *Hyphaene thebaica,* DSN = *Detarium senegalensce,* ZT = *Ziziphus jujuba,* DG = *Dialium guineense* and DS = *Diospyrosme spiliformis.* Each parameter is assessed qualitatively with three levels of presence denoted as +, ++, and +++, representing low, moderate, and high levels, respectively while (-) denotes absence

**Table 2: Quantitative Phytochemicals Composition of *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* Aqueous Fruits Extract**

| Phytochemical parameters (mg/g) | HT | DSN | ZJ | DG | DS |
|---|---|---|---|---|---|
| **Alkaloids** | $0.97 \pm 0.06^{a}$ | $1.03 \pm 0.06^{b}$ | $0.44 \pm 0.06^{c}$ | $0.75 \pm 0.15^{d}$ | $0.09 \pm 1.00^{e}$ |
| **Flavonoids** | $4.80 \pm 0.26^{a}$ | $6.07 \pm 0.12^{b}$ | $0.84 \pm 0.05^{c}$ | $0.77 \pm 0.09^{c}$ | $0.70 \pm 0.01^{d}$ |
| **Phenols** | ND | ND | $0.40 \pm 0.04^{a}$ | $0.42 \pm 0.03^{a}$ | $0.30 \pm 0.01^{b}$ |
| **Tannins** | ND | $4.3 \pm 0.10^{a}$ | $2.44 \pm 0.06^{b}$ | $1.21 \pm 0.09^{c}$ | $3.30 \pm 0.20^{d}$ |
| **Saponins** | $2.53 \pm 0.06^{a}$ | $3.37 \pm 0.06^{b}$ | $3.14 \pm 0.15^{b}$ | $1.06 \pm 0.04^{c}$ | $2.1 \pm 0.10^{a}$ |
| **Steroids** | $2.24 \pm 0.11^{a}$ | $3.17 \pm 0.1^{b}$ | $2.87 \pm 0.06^{a}$ | $0.90 \pm 0.10^{c}$ | $0.84 \pm 0.06^{c}$ |
| **Terpenoids** | $2.11 \pm 0.01^{a}$ | $2.90 \pm 0.10^{b}$ | $2.50 \pm 0.10^{b}$ | $0.99 \pm 0.72^{c}$ | $0.92 \pm 0.03^{c}$ |
| **Glycoside** | $2.19 \pm 0.27^{a}$ | $3.27 \pm 0.15^{b}$ | $1.86 \pm 0.05^{c}$ | $0.77 \pm 0.06^{d}$ | $0.79 \pm 0.07^{d}$ |

Key: ND = Not detected, HT = *Hyphaene thebaica,* DSN = *Detarium senegalensce,* ZT = *Ziziphus jujuba,* DG = *Dialium guineense* and DS = *Diospyrosme spiliformis*, . Values in the same row having similar superscripts are statistically similar, while values in the same row with different superscript are statistically different, = ANOVA test, Value were presented as Mean ± SD, $P \leq 0.05$ is statistically considered significant

**Evaluation of the mineral contents of *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* Aqueous Fruits Extract**

The mineral composition in the aqueous extracts of five distinct fruits species (Table 3). *Hyphaene thebaica* exhibits the highest potassium content (91.21 mg/Kg), significantly higher than other species. *Dialium guineense* demonstrates remarkably low potassium levels (3.44 mg/Kg). *Hyphaene thebaica* again leads with the highest magnesium content (71.44 mg/Kg). *Detarium senegalensce* and *Diospyrosme spiliformis* display considerably low magnesium levels (5.25 mg/Kg and 31.07 mg/Kg, respectively). *Hyphaene thebaica* maintains the highest calcium concentration (68.84 mg/Kg). *Dialium guineense* revealed the lowest calcium content (2.97 mg/Kg). *Hyphaene thebaica* stands out with the highest sodium levels (53.43 mg/Kg) while the *Detarium senegalensce* possesses the lowest sodium content (1.79 mg/Kg). Interestingly, *Hyphaene thebaica* exhibits a highest iron content (28.74 mg/Kg), while *Dialium guineense* and *Diospyrosme spiliformis* revealed relatively low iron levels (1.30 mg/Kg and 24.29 mg/Kg, respectively). *Hyphaene thebaica* and *Diospyrosme spiliformis* revealed the manganese levels at (6.43 mg/Kg and 3.15 mg/Kg, respectively). *Detarium senegalensce* presents the highest manganese content (3.36 mg/Kg). *Hyphaene thebaica* exhibits the highest zinc (4.80 mg/Kg) and copper (3.90 mg/Kg) levels. *Dialium guineense* demonstrates the lowest zinc (1.68 mg/Kg) and copper (1.00 mg/Kg) concentrations. All the observed differences are statistically significant, as indicated by the p-values ($P \leq 0.001$).

**2, 2-Diphenyl-1-picrylhydrazyl (DPPH) Inhibition of *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* Aqueous Fruits Extract**

The DPPH inhibition percentages of aqueous fruits extracts at different concentrations (µg/ml) of *Hyphaene thebaica* (HT), *Detarium senegalensce* (DSN), *Ziziphus jujuba* (ZJ), *Dialium guineense* (DG), and *Diospyrosme spiliformis* (DS), alongside a standard (ascorbic acid) were evaluated. The inhibitory effect is a measure of the antioxidant potential of these fruits, with lower $IC_{50}$ values indicating higher antioxidant activity. At 100 µg/ml, *Hyphaene thebaica* (HT) exhibits the highest inhibition (83.50%) among the tested concentrations, suggesting its substantial antioxidant properties. *Detarium senegalensce* (DSN) displays a consistent increase in inhibition with rising concentrations, reaching 66.52% at 100 µg/ml. Its performance indicates a promising antioxidant nature. *Ziziphus jujuba* (ZJ) showcases moderate inhibition across concentrations, with a maximum of 62.87% at 100 µg/ml, considered as moderate antioxidant. *Dialium guineense* (DG) shows an upsurge in inhibition with increasing concentrations, peaking at 86.95% at 100 µg/ml. This suggests DG as a potent antioxidant fruit. While *Diospyrosme spiliformis* (DS) exhibits a gradual increase in inhibition, with a maximum of 88.18% at 100 µg/ml, highlighting its commendable antioxidant potential. As expected, the standard (ascorbic acid) shows high inhibition at all concentrations, reaching 89.10% at 100 µg/ml, validating its well-known antioxidant efficacy. The IC50 values (concentration required to inhibit 50% of DPPH radicals) provide a clear comparison of the fruits' antioxidant potency. DS displays the lowest IC50 value (39.28 µg/ml), indicating its high efficacy in neutralizing free radicals. In contrast, HT, DSN, ZJ, and DG have relatively higher IC50 values, signifying a slightly lower antioxidant potency compared to DS. These findings emphasize the diverse antioxidant capabilities of the studied fruits. *Diospyrosme spiliformis* (DS) emerges as a standout, exhibiting robust antioxidant activity, closely followed by *Dialium guineense* (DG). These results not only contribute to the understanding of the antioxidant potential of these fruits but also pave the way for further research and exploration in the field of natural antioxidants and their health benefits (Table 4).

**Nitric oxide (NO) Radicals scavenging activity of *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* Aqueous Fruits Extract**

The nitric oxide (NO) radicals scavenging activity of *Hyphaene thebaica* (HT), *Detarium senegalensce* (DSN), *Ziziphus jujuba* (ZJ), *Dialium guineense* (DG), and *Diospyrosme spiliformis* (DS) were assessed. The evaluation is conducted at different concentrations (20 µg/ml, 40 µg/ml, 60 µg/ml, 80 µg/ml, and 100 µg/ml) of the fruit extracts, with Ascorbic Acid as reference. The finding reveals a concentration-dependent response in the NO radicals scavenging activity for all the fruits and ascorbic acid. As the concentration of the fruit extracts increases, their ability to scavenge NO radicals also intensifies. This concentration-dependent behavior underscores the

potential health benefits associated with these fruits when consumed in higher quantities. Upon comparing the NO radicals scavenging activity among the fruits, it is evident that *Diospyrosme spiliformis* (DS) exhibits consistently higher scavenging activity across all concentrations, closely followed by *Ziziphus jujuba* (ZJ) and *Dialium guineense* (DG). *Hyphaene thebaica* (HT) and *Detarium senegalensce* (DSN) demonstrate slightly lower scavenging activity but are still considerable contributors to NO radicals scavenging. Ascorbic Acid, a well-known antioxidant, also exhibits significant NO radicals scavenging activity, indicating its effectiveness in this context. The IC50 values represent the concentration at which 50% of NO radicals are scavenged. Lower IC50 values signify higher efficacy in scavenging NO radicals (Table 5).

**Table 3: Mineral content of *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* Aqueous Fruits extract**

| Minerals (mg/Kg) | HT | DSN | ZJ | DG | DS |
|---|---|---|---|---|---|
| **Potassium (K)** | 91.21 ± 1.10$^{a}$ | 71.20 ± 1.25$^{b}$ | 40.34 ± 0.15$^{c}$ | 3.44 ± 0.50$^{d}$ | 51.74 ± 0.44$^{e}$ |
| **Magnesium (Mg)** | 71.44 ± 0.41$^{a}$ | 5.25 ± 0.05$^{b}$ | 3.25 ± 0.13$^{c}$ | 2.46 ± 0.40$^{d}$ | 31.07 ± 1.01$^{e}$ |
| **Calcium (Ca)** | 68.84 ± 0.48$^{a}$ | 31.31 ± 0.01$^{b}$ | 24.82 ± 0.23$^{c}$ | 2.97 ± 0.05$^{d}$ | 48.27 ± 0.40$^{e}$ |
| **Sodium (Na)** | 53.43 ± 0.22$^{a}$ | 4.24 ± 0.05$^{b}$ | 3.04 ± 0.17$^{c}$ | 1.79 ± 0.26$^{d}$ | 39.04 ± 0.07$^{e}$ |
| **Iron (Fe)** | 28.74 ± 0.65$^{a}$ | 6.34 ± 0.25$^{b}$ | 1.87 ± 0.05$^{c}$ | 1.30 ± 0.01$^{c}$ | 24.29 ± 0.18$^{e}$ |
| **Manganese (Mn)** | 6.43 ± 0.52$^{a}$ | 3.36 ± 0.12$^{b}$ | 2.18 ± 0.14$^{c}$ | 2.41 ± 0.14$^{c}$ | 3.15 ± 0.05$^{b}$ |
| **Zinc (Zn)** | 4.80 ± 0.11$^{a}$ | 2.76 ± 0.16$^{b}$ | 1.79 ± 0.10$^{c}$ | 1.68 ± 0.02$^{c}$ | 2.40 ± 0.12$^{b}$ |
| **Cupper (Cu)** | 3.90 ± 0.11$^{a}$ | 2.44 ± 0.18$^{b}$ | 1.51 ± 0.07$^{c}$ | 1.00 ± 0.11$^{d}$ | 1.74 ± 0.17$^{c}$ |

Key: HT = *Hyphaene thebaica,* DSN = *Detarium senegalensce,* ZT = *Ziziphus jujuba,* DG = *Dialium guineense and* DS = *Diospyrosme spiliformis*, Values in the same row having similar superscripts are statistically similar, while values in the same row with different superscript are statistically different = ANOVA test, Values are presented as Mean ± SD, $P \leq 0.05$ is statistically considered significant

**Table 4: DPPH Inhibition of Aqueous extract of *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* fruits**

| Concentrations (µg/ml) | HT | DSN | ZJ | DG | DS | Ascorbic Acid (STD) |
|---|---|---|---|---|---|---|
| **20** | 40.81±0.55$^{a}$ | 44.03±0.30$^{b}$ | 37.20 ± 0.56$^{c}$ | 41.71 ± 0.61$^{a}$ | 47.00±0.30$^{d}$ | 56.29±0.20$^{e}$ |
| **40** | 51.22±0.11$^{a}$ | 48.36 ± 0.30$^{b}$ | 39.27 ± 0.07$^{c}$ | 53.13 ± 0.57$^{d}$ | 52.64±0.60$^{a}$ | 63.56±0.42$^{e}$ |
| **60** | 66.98±0.55$^{a}$ | 53.85 ± 0.62$^{b}$ | 43.18 ± 0.07$^{c}$ | 61.30 ± 0.13$^{d}$ | 73.55 ± 0.42$^{e}$ | 71.54±0.44$^{f}$ |
| **80** | 71.25±0.23$^{a}$ | 39.17 ± 0.35$^{b}$ | 56.56 ± 0.43$^{c}$ | 72.33 ± 0.23$^{a}$ | 81.40 ± 0.14$^{d}$ | 82.34±0.91$^{d}$ |
| **100** | 83.50±0.45$^{a}$ | 66.52 ± 0.72$^{b}$ | 62.87 ± 0.70$^{c}$ | 86.95 ± 0.63$^{d}$ | 88.18 ± 0.33$^{d}$ | 89.10±0.42$^{d}$ |
| **$IC_{50}$** | 53.54±0.39$^{a}$ | 46.37 ± 0.47$^{b}$ | 50.28 ± 0.30$^{c}$ | 41.67 ± 0.57$^{d}$ | 39.28 ± 0.41$^{e}$ | 23.23±1.26$^{f}$ |

Key: STD = Standard, HT = *Hyphaene thebaica,* DSN = *Detarium senegalensce,* ZT = *Ziziphus jujuba,* DG = *Dialium guineense and* DS = *Diospyrosme spiliformis*, Values in the same row having similar superscripts are statistically similar, while values in the same row with different superscript are statistically different = ANOVA test, Mean ± SD, $P \leq 0.05$ is statistically considered significant

**Table 5: Nitric oxide (NO) Radicals scavenging activity of *Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense* and *Diospyros mespiliformis* fruits**

| Concentrations (µg/ml) | HT | DSN | ZJ | DG | DS | Ascorbic Acid |
|---|---|---|---|---|---|---|
| **20** | 24.11±0.59$^{a}$ | 34.40±0.36$^{b}$ | 49.27±0.30$^{c}$ | 36.48±0.30$^{d}$ | 31.41±0.22$^{e}$ | 46.36±0.13$^{f}$ |
| **40** | 28.43±0.67$^{a}$ | 41.60±0.35$^{b}$ | 58.30±0.25$^{c}$ | 39.58±0.37$^{d}$ | 37.14±0.13$^{e}$ | 53.40±0.24$^{f}$ |
| **60** | 35.60±0.75$^{a}$ | 56.15±0.39$^{b}$ | 64.63±0.34$^{c}$ | 46.2±0.20$^{d}$ | 49.40±0.09$^{e}$ | 62.49±0.12$^{f}$ |
| **80** | 54.41±0.13$^{a}$ | 61.38±0.23$^{b}$ | 80.22±0.12$^{c}$ | 53.56±0.40$^{a}$ | 57.29±0.43$^{d}$ | 79.15±0.31$^{c}$ |
| **100** | 68.27±0.13$^{a}$ | 74.40±0.14$^{b}$ | 93.68±0.71$^{c}$ | 68.22±0.40$^{a}$ | 71.64±0.40$^{d}$ | 89.41±0.08$^{e}$ |
| **$IC_{50}$** | 44.95±0.54$^{a}$ | 34.71±0.08$^{b}$ | 49.42±0.33$^{c}$ | 36.33±0.12$^{d}$ | 32.25±0.90$^{e}$ | 46.13 ± 0.53$^{f}$ |

Key: HT = *Hyphaene thebaica,* DSN = *Detarium senegalensce,* ZT = *Ziziphus jujuba,* DG = *Dialium guineense* and DS = *Diospyrosme spiliformis*. Values in the same row having similar superscripts are statistically similar, while values in the same row with different superscript are statistically different = ANOVA test, Mean ± SD, $P \leq 0.05$ is statistically considered significant

## DISCUSSION

Phytochemicals evaluation, mineral elements and antioxidants (DPPH inhibition, and nitric oxide) scavenging activity are important factors to consider when assessing the health benefits of commonly consumed fruits. These factors contribute to the fruits' overall nutritional and medicinal value. Phytochemical evaluation involves the analysis of bioactive compounds present in fruits, such as flavonoids, phenolic compounds, and other antioxidants, which contribute to their health-promoting properties (Olaide *et al.,* 2019*,* Jafri *et al.,* 2022). The presence of phytochemicals in plants has been linked to their antioxidant and other health-promoting properties (Akhtar *et al.,* 2018*,* Jafri *et al.,* 2022).

Previous studies have also reported the presence of saponins, steroids, terpenoids, and glycosides in medicinal plants, aligning with the findings of the current study. The presence of alkaloids, flavonoids, phenols, and terpenoids is in line with previous studies by Sarwar *et al.* (2013). Phytochemicals are naturally occurring compounds found in plants that possess various bioactive properties, contributing to their medicinal importance. Among the phytochemicals identified in commonly consumed aqueous fruit extracts of *Hyphaene thebaica* (HT), *Detarium senegalensce* (DSN), *Ziziphus Jujuba* (ZJ), *Dialium guineense* (DG), and *Diospyrosme spiliformis* (DS) includes alkaloids, flavonoids, phenols, tannins, saponins, steroids, terpenoids, and glycosides . Which play pivotal roles in human health (Bravo, 1998*,* Cushnie and Lamb, 2005*,* Harborne, 1993*,* Ojewole, 2005). Alkaloids, such as caffeine and nicotine are nitrogen-containing compounds known for their pharmacological activities, including analgesic, antimicrobial, and anti-inflammatory effects (Cushnie and Lamb, 2005). For instance, caffeine has been studied for its potential to alleviate pain and enhance athletic performance (Goldstein *et al*., 2010). Flavonoids, abundant in fruits and vegetables, exhibit antioxidant, anti-inflammatory, and anticancer properties (Bravo, 1998). These compounds, including quercetin and kaempferol, have been associated with reduced risk of chronic diseases, such as cardiovascular disease and cancer (Erdman *et al*., 2009).

Phenols are aromatic compounds found in fruits with antioxidant and antimicrobial activities (Bravo, 1998). Studies suggest that phenolic compounds, such as resveratrol and ellagic acid, may help prevent oxidative stress-related diseases and inhibit the growth of pathogenic microorganisms (Erdman *et al*., 2009*,* Cushnie and Lamb, 2005). Tannins, known for their astringent properties, possess antibacterial and antiviral effects (Bravo, 1998). Epigallocatechin gallate (EGCG), a type of tannin found in green tea, has been extensively studied for its potential health benefits, including anticancer and antiviral properties (Yiannakopoulou, 2020).

Saponins, characterized by their foaming properties, exhibit cholesterol-lowering, immunomodulatory, and anticancer activities (Harborne, 1993). For example, ginsenosides, a type of saponin found in ginseng, have been shown to modulate immune function and protect against cancer (Radad *et al*., 2016). Steroids, such as phytosterols, play essential roles in hormone regulation and possess anti-inflammatory properties (Bravo, 1998). Phytosterols,

found in various fruits and vegetables, have been studied for their potential to lower cholesterol levels and reduce inflammation (Rocha *et al*., 2016). Terpenoids, diverse in structure and function, exhibit pharmacological activities, including antimicrobial, antiviral, and anti-inflammatory effects (Harborne, 1993). For instance, carotenoids, a type of terpenoid found in fruits like tomatoes and carrots, have been associated with reduced risk of age-related macular degeneration and certain cancers (Krinsky *et al*., 2003).

Glycosides, comprising a sugar moiety attached to a non-sugar compound, have various therapeutic effects, such as cardiovascular protection and anticancer properties (Ojewole, 2005). For example, cardiac glycosides, found in plants like foxglove, have been used to treat heart failure and arrhythmias (Hasenfuss and Pieske, 2002). These findings underscore the medicinal importance of phytochemicals in commonly consumed aqueous fruit extracts and highlight their potential as natural sources of bioactive compounds with various health benefits. By comparing the quantitative phytochemical presence in the current study with previous studies, researchers can gain insights into the consistency and variability of phytochemical components across different fruit extracts, contributing to the broader understanding of medicinal plant chemistry and potential applications. One study analyzed the phytochemical composition of medicinal plants from Uttarakhand, Western Himalaya, and found that phenolic compounds, flavonoids, and terpenoids were highly abundant classes of phytochemicals (Tiwari *et al.,* 2023). Another study analyzed the phytochemical composition of different parts of milk thistle and found the presence of alkaloids, glycosides, flavonoids, and phenols (Javeed *et al*., 2022).

Fruits are a good source of essential mineral elements such as potassium, magnesium, and calcium, which are important for various physiological functions in the body (Olaide *et al.,* 2019). The mineral elements present in these fruits can contribute to their nutritional value. Elements such as calcium, potassium, magnesium, and iron are essential for various physiological functions in the body. The accumulation of mineral elements in different fruit species can vary based on factors such as soil type, plant species, and environmental conditions (Thakur *et al.,* 2022). The comparison with previous studies that are similar with the current study can provide valuable insights into the mineral composition of plant extracts. A study evaluated the mineral nutrient composition of edible wild plants and found that mineral element content was high in *Amaranthus viridis* and *Verbena officinalis* (Guil-Guerrero *et al.,* 1998). Another study evaluated the inorganic content of six under used wild berries from Portugal and found that they were potential new sources of essential minerals (Imensek *et al.,* 2021).

Study determined the elemental and nutritive values of leaf of 10 selected wild medicinal plants and found that *Acer pictum* had high mineral content (Kumar *et al.,* 2021). While these studies did not evaluate the same plant species as the current study, they provide a comparative perspective on the mineral composition of different fruits species. It is important to note that the mineral content of fruits can depend on numerous factors, such as the type and chemical composition of the soil, soil fertility, and the root-soil interface (Imensek *et al.,* 2021).

Calcium and other minerals present in these fruits, such as magnesium and manganese, are essential for maintaining bone density and preventing osteoporosis (Weaver et al., 2016*,* Volpe, 2013). Consuming fruits rich in these minerals may help support bone health and reduce the risk of fractures, especially in aging populations.

Potassium (K) plays a crucial role in maintaining fluid balance and electrolyte levels in the body.

Supports proper nerve function and muscle contraction. May help lower blood pressure and reduce the risk of stroke and cardiovascular diseases (Aburto *et al*., 2013). Magnesium (Mg) Essential for over 300 enzymatic reactions in the body. Contributes to energy metabolism, muscle function, and bone health. Supports cardiovascular health by regulating blood pressure and heart rhythm (Volpe, 2013). Calcium (Ca): Vital for bone and teeth formation, muscle function, and nerve transmission.

Helps prevent osteoporosis and maintain bone density, especially in aging populations (*Weaver et al*., 2016). Sodium (Na) Necessary for maintaining fluid balance and cellular function. Regulates blood pressure and electrolyte levels in the body. Excessive sodium intake may increase the risk of hypertension and cardiovascular diseases (Aburto *et al*., 2013). Iron (Fe) Essential for oxygen transport in the blood and energy metabolism. Supports cognitive function,

immune health, and overall vitality. Iron deficiency can lead to anemia and fatigue (Camaschella, 2019).

Manganese (Mn) plays a role in antioxidant defense, bone formation, and carbohydrate metabolism. Supports wound healing, collagen production, and immune function. Manganese deficiency may impair growth and skeletal development (Rafique *et al*., 2017). Zinc (Zn) Essential for immune function, wound healing, and DNA synthesis. Supports growth and development, reproductive health, and skin integrity. Zinc deficiency can impair immune response and increase susceptibility to infections (Shankar and Prasad, 1998). Copper (Cu) Necessary for the formation of red blood cells, collagen production, and iron metabolism. Supports cardiovascular health, energy production, and connective tissue integrity. Copper deficiency may lead to anemia, bone abnormalities, and impaired immune function (Wapnir, 1998).

The evaluation of antioxidants in fruits is crucial for understanding their potential health benefits. Antioxidants are compounds that can prevent or slow damage to cells caused by free radicals, which are unstable molecules produced by the body as a result of normal metabolism or exposure to environmental factors such as radiation and cigarette smoke. Antioxidants can neutralize free radicals by donating an electron, which stabilizes the molecule and prevents it from causing damage (Saha *et al.,* 2004).

The current study presents the DPPH inhibition percentages of aqueous extracts from *Hyphaene thebaica (HT), Detarium senegalensce (DSN), Ziziphus jujuba (ZJ), Dialium guineense (DG),* and *Diospyrosme spiliformis (DS)*, alongside a standard (ascorbic acid). There are several studies on the antioxidant activities of fruits using DPPH inhibition assay. One study evaluated the antioxidant activity of seven commercially available fruits, including blueberry, black and red raspberry extracts, and found that they showed the highest percentage of DPPH radical inhibition ranging from 38.5% to 87.9%, 64.2% to 89% (Basu and Maier, 2016). A study by Saleem *et al.* (2023) investigated the antioxidant and antibacterial effects of citrus fruits peels extracts. It found that lemon peels exhibited the highest free radical scavenging activity (93.1%) of DPPH, while the least activity (78.6%) was shown by mousami peels (Saleem *et al.,* 2023). Another study on the metabolomic profiling and antioxidant activities of *Hyphaene thebaica* found that the fruit exhibited antioxidant activities (Taha *et al.,* 2020). A study by Thi *et al* (2020) on the screening for antioxidant activity of vegetable and fruit by-products found that most samples had weak antioxidant activity, and the effect of antioxidants on DPPH radical scavenging was due to their hydrogen donating ability (Thi *et al.,* 2020). Based on the comparison with previous studies, it is evident that the current study aligns with the broader research landscape on antioxidant activities of fruits and their extracts.

Nitric oxide scavenging activity is an important aspect of the antioxidant potential of fruits. It involves the ability of a substance to inhibit the production of nitric oxide radicals, which are involved in various physiological processes and can contribute to oxidative stress when present in excess (Saha *et al.,* 2004*,* Skouta *et al.,* 2017). Nitric oxide (NO) scavenging activity is another method used to measure the antioxidant activity of a substance. NO is a free radical that can cause damage to cells and tissues. Antioxidants can scavenge NO by donating an electron, which stabilizes the molecule and prevents it from causing damage. The lower the concentration of a substance required to scavenge NO, the higher its antioxidant activity (Kumar and Berlin, 2017*,* Olaide *et al.,* 2019). Nitric oxide is involved in various physiological processes, and its scavenging activity by fruit extracts can indicate their potential role in maintaining health and preventing oxidative stress-related disorders (Saha *et al.,* 2004*,* Olaide *et al.,* 2019). This study presents the nitric oxide (NO) radicals scavenging activity of five commonly consumed fruits, including *Hyphaene thebaica* (HT), *Detarium senegalensce* (DSN), *Ziziphus jujuba* (ZJ), *Dialium guineense* (DG), and *Diospyrosme spiliformis* (DS), at different concentrations. The study concludes that *Diospyrosme spiliformis* (DS) exhibits consistently higher scavenging activity across all concentrations, closely followed by *Ziziphus jujuba* (ZJ) and *Dialium duineense* (DG), while *Hyphaene thebaica* (HT) and *Detarium senegalensce* (DSN) demonstrate slightly lower scavenging activity but are still considerable contributors to NO radicals scavenging. Ascorbic Acid, a well-known antioxidant, also exhibits significant NO radicals scavenging activity, indicating its effectiveness in this context. The study provides valuable insights into the NO radicals scavenging activity of commonly consumed fruits, highlighting their potential health benefits. *Diospyrosme spiliformis* (DS) emerges as a standout fruit with remarkable NO radicals scavenging efficacy, making it a promising candidate for further exploration in the field of health and nutrition. The

diverse array of phytochemicals found in these fruits possess potent antioxidant properties that help neutralize harmful free radicals and reduce oxidative stress (Bravo, 1998*,* Harborne, 1993). Antioxidants play a crucial role in protecting cells from damage and may help prevent chronic diseases such as cancer, diabetes, and neurodegenerative disorders (Halliwell, 2007).

**CONCLUSION**

The comprehensive phytochemicals, mineral contents, DPPH inhibition, and nitric oxide (NO) radicals scavenging activity of the aqueous extracts from five different fruits species (*Hyphaene thebaica, Detarium senegalensce, Ziziphus jujuba, Dialium guineense*, and *Diospyrosme spiliformis*) has provided valuable insights into their biochemical diversity and potential applications. The phyto-constituents analysis revealed significant differences between the various phytochemical compounds presence in the fruits species, suggesting varied potential medicinal and nutritional properties, the mineral contents demonstrated substantial variations in essential elements like potassium, magnesium, calcium, sodium, iron, manganese, zinc, and copper among the fruits species. While the DPPH and NO radicals scavenging assay revealed *Diospyrosme spiliformis* emerged as a standout, exhibiting robust antioxidant activity.

**ETHICAL APPROVAL**

This study does not contain any studies involving human or animal subjects.

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**COMPETING INTERESTS**

No competing interests exist between the authors of this study.

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