ASM Sc. J., 19, 2024

https://doi.org/10.32802/asmscj.2023.1511

Evaluation of the Vitamin E Content, Phenolic Compounds Profile and Antioxidant Activity of Some Citrus Seeds Oils

A.M. Olatunya[1]*, A.J. Adesina[1], O.Y. Komolafe[2], A.S. Anifowose[1], A.E. Ikuesan[1], A. Adeshina[1], O. Sodiq[1], A. Aladesanmi[1] and E.T. Akintayo[1]

[1]*Department of Chemistry, Ekiti State University, P.M.B 5363, Ado Ekiti, Ekiti State, Nigeria*

[2]*Department of Science Laboratory Technology, Rufus Giwa Polytechnic, P.M.B 1019, Owo, Ondo State, Nigeria.*

The aim of this research work is to evaluate the vitamin E contents, phenolic compound profiles and the antioxidant activity of seed oils extracted from fruits of some citrus plants and to determine the correlation between these parameters and antioxidant activity of the seed oils. The oils were extracted using Soxhlet extractor, the vitamin E content and the phenolic compounds profiles were determined using chromatographic technique while their antioxidant abilities were investigated using 1, 1 – diphenyl- 2-picrylhydrazyl (DPPH) radical and ferric reducing antioxidant power (FRAP) assays. The oils had relatively high vitamin E contents (7.28- 24.48mg/100g) with grapefruit significantly having the highest amount. Gallic acid and some other phenolic compounds were detected in appreciable amount in the oils and the oils showed good antioxidant ability. There was a strong correlation between the vitamin E content, phenolic compounds profile and antioxidant activity of the extracted oil. Therefore, seeds from these plants could be used as sources of oils for pharmaceutical, cosmetics and food industries to produce dietary antioxidants and bioactive compounds thus helping to prevent occurrence of certain deadly diseases associated with generation of free radicals instead of regarding them as waste.

Keywords: Vitamin E content; Gallic acid; Antioxidant; Citrus seed oils; Cosmetics industry

I. INTRODUCTION

The major group of compounds that makes up vitamin E are the tocopherols and tocotrienols, which are also referred to as tocols. Tocols are amphipathic compounds that have been found to possess numerous health benefits (Olatunya *et al.*, 2019). They act as antioxidants and could therefore help to neutralise substances that can damage the genetic materials by oxidation (Rudzińska *et al.*, 2016).

Phenolic compounds, generally referred to as polyphenols, could be found in all plants and, thus, are obtained from diets (Olatunya, 2021). Polyphenols are secondary metabolites of plants, and they include some common intermediate and phenylalanine that could be classified into four major groups, which are: flavonoids, phenolic acids, stilbenes, phytosterols (Sales & Resurreccion, 2010). These compounds have also been found to have high antioxidant properties which makes them to be of good health benefits.

The presence of these compounds in food and diets coupled with their antioxidant properties, health benefits and their ability to prevent various diseases associated with oxidative stress for example cancer, cardiovascular and neurodegenerative diseases has generated increase interest and search for food sources of these compounds by researchers and food manufacturers (Sales & Resurreccion, 2010).

Antioxidants are substances which, when present in the diets they help to protect human bodies against certain diseases such as cardiac disease, arthritis etc. Their mode of action is to remove the dangerous effect of free radicals in the body system by slowing down the oxidation process of these free radicals (Barja, 2014; Mathur *et al.*, 2011;

*Corresponding author's e-mail: ayomadewa.olatunya@eksu.edu.ng

Olatunya & Akintayo, 2017). It has been found that the health benefits of some natural products are in close association with their antioxidant activities by reducing oxidative phenomena and, thus, lowering the occurrence of reactive oxygen species-related diseases, thereby preventing their damage to biological cells (Bunea *et al*., 2011; Yang *et al*., 2017). Therefore, a sufficient amount of antioxidant in the diet are necessary to boost the body's defence system and to counter reactive oxygen species. Thus, the increasing search for plant-based natural antioxidants.

Citrus species are rich in polyphenols, flavonoids and terpenoids (Oboh & Ademosun, 2012). The citrus group include different types of fruits like oranges, tangerines, mandarins, clementine, lemon, lime and grapefruits. These fruits are readily available and are widely taken and used as juice. The fruits contain peels and seeds, which are normally regarded as waste and are discarded after taken the juice of the fruits. The peels and seeds of these citrus fruits have been found to contain essential oils which are of various economic and industrial importance. Several works have been done on the antioxidant activity of essential oil of some citrus species (Ayoola *et al*., 2008; Javed *et al*., 2014; Olatunya & Akintayo, 2017; Yang & Kang, 2013), but few works to the best of our knowledge have been done on the vitamin E content and profiles of phenolic compounds present in the oils extracted from the seeds of these citrus species.

It has been found that polyphenolic compounds and vitamins help to promote the antioxidant abilities of substances (Niki, 2014; Yeh & Yen, 2003). Therefore, this research work was conducted to determine the quantity of vitamin E and the profiles of phenolic compound present in oils extracted from seeds of four different species of citrus fruits and determine the antioxidant activities of these oils, thereafter, finding the correlation between the vitamin E content, phenolic compounds, and the antioxidant activity of the seed oils.

II. MATERIALS AND METHOD

The citrus fruits used lime (*Citrus aurantifolia*), grapefruit (*Citrus paradisi*), tangerine (*Citrus reticulata*) and tangelo (*C. tangelo*)) were purchased from markets within Ado Ekiti metropolis (7.6124oN, 5.2371oE), Ekiti State, Nigeria. The fruits were extracted, and the seeds were removed. The seeds were washed several times under running water and then with distilled water before drying under mild sunlight for five days. The seeds were milled using an electric blender and was stored in an airtight container prior to further analysis.

A. Extraction of Oil

About 150g of the powdered samples of each seed flour was weighed and extracted using n-hexane for 6 hours at a temperature of 65 – 70oC according to the method of Redfern *et al.* (2014) with slight modification. After extraction, the oil was concentrated using a rotary evaporator.

B. Determination of Vitamin E contents

To quantify the tocols in the seed oils, the methods of Du and Ahn (2002), and Ahsan *et al.* (2015) were used with slight modifications. A total of 100-150 mg of oil samples were weighed into 50 ml Erlenmeyer flasks and esterified with 10 ml of a freshly prepared mixture containing ethanol, 33% KOH solution, and ascorbic solution (to prevent oxidation of the tocols during esterification). Sample were homogenised and incubated at 50 °C for 1 hour, 5 ml each of deionised water and redistilled hexane was added. The mixture was then shaken thoroughly and allowed to stand for about 15 hours, the phase was separated and the unsaponifiable matter was transferred to a scintillation vial under nitrogen. To derive tocopherols, pyridine, and a mixture of 99% bistrifluoroacetamide and trimethyl chlorosilane were added, and to derive tocotrienols, trimethyl silane was added. A total of 2 ml of internal standard solution and 7 ml of hexane were added, and the lipids were derived overnight at room temperature before analysis by gas chromatography (GC).

GC equipment and conditions: Hewlett-Packard Packed 6890 Gas Chromatograph (Agilent Technologies, Inc., Wilmington, DE, USA) equipped with flame ionisation detector. The capillary column used was 30 m × 0.25 mm × 0.25 μm for tocopherol and 15 m × 0.25 mm × 0.15 μm supported on $BaCO_3$ for tocotrienol. The chromatographic conditions were as follows: initial temperature 180 °C (10 min); increased from 8 °C/min to 260 °C then to 280 °C at 2 °C/min, maintained at 13 min. The injector and detector temperatures were 290 °C and 300 °C, respectively. Helium was used as the carrier gas at a flow rate of 1.2 and 2.5 mL/min for tocopherols and tocotrienols, respectively. Peak areas were measured using a Hewlett-Packard Packard 7860 integrator (Agilent Technologies, Inc.).

C. Determination of Phenolic Compounds

A total of 50 mg of the sample was extracted with 5 ml of 1 M NaOH for 16 hours on a shaker at ambient temperature, as described by Provan *et al.* (1994). After extraction, the sample was centrifuged, rinsed with water, centrifuged again and the supernatants were combined and place in a disposable glass test tube and heated at 90 °C for 2 hours to release the conjugated phenolic compounds. The heated extract was cooled, titrated with 4M HCl to pH less than 2.0 diluted to 10 ml, with deionised water and then centrifuged to remove the precipitate. The supernatant was kept for subsequent purification and analysed using gas chromatography. The GC used for the analysis is HP 1 column length – 30m, injection temperature – 250 °C, detector – FID, carrier gas – nitrogen, initial temp – 60 °C for 5 min, first-rate – 15 °C for 15 min and second rate – 10 °C for 4 min.

D. Determination of the Antioxidant Activity

1. 1, 1 - diphenyl -2-picrylhydrazyl free radical scavenging ability

The free radical scavenging ability of the oil against DPPH free radical was evaluated as described by Gyamfi *et al.* (1999). Briefly, an appropriate dilution of the oil (1 ml) was mixed with 1 ml 0.4 mM DPPH radicals in methanolic solution. The mixture was left in the dark for 30 min, and the absorbance was taken and recorded as absorbance of sample (Abs sample) at 516 nm. The control was carried out by using 2 ml DPPH solution without the test samples, and the absorbance taken and was recorded as absorbance of reference (Abs ref). The percentage DPPH free radical scavenging ability was subsequently calculated using the equation below:

$$\text{Percentage DPPH radical scavenging ability} = \frac{Abs_{ref} - Abs_{sample}}{Abs_{ref}} \times 100$$

2. FRAP Assay (Ferric reducing antioxidant power)

The reducing property of the oil was determined by assessing the ability of the oil to reduce $FeCl_3$ solution as described by Oyaizu (1986). A 2.5 ml aliquot of the oil was mixed with 2.5 ml of 200 mM sodium phosphate buffer (pH 6.6) and 2.5 ml of 1% potassium ferricyanide. The mixture was incubated at 50 °C for 20 min, and then 2.5 ml of 10 % trichloroacetic acid was added. This was followed by centrifugation at 3000 rpm for 10 min. 5 ml of the supernatant was mixed with an equal volume of water and 1 ml of 0.1 % ferric chloride. The absorbance was measured at 700 nm after about 10 min. The procedure was repeated three times for all the samples and for Butylated hydroxytoluene (BHT). The mean values were calculated and recorded; the ferric reducing ability of the sample was compared with that of BHT. Higher absorbance of the reaction mixture indicated higher reducing power of the samples.

E. Statistical Analysis

All values were expressed as means of triplicate analysis. Tukey's Multiple comparison test was performed to compare differences among the means. Pearson correlation test was also performed to determine the correlation between all the investigated parameters. All analysis was done using GraphPad Prism program version 5 for windows (Graph Pad Software Inc; San Diego, CA, USA). Statistical significance among means were determined at $p<0.05$.

III. RESULT AND DISCUSSION

A. Extraction of Oil

Generally, the oil yield of the samples ranged between 26.87 – 44.90 % as shown in Table 1. The odour of the oils ranged from pleasant to pleasant intense, and they have a pale- or light-yellow colouration.

Table 1. Some physical properties of the extracted citrus seed oil.

Physical properties	Lime	Grapefruit	Tangerine	Tangelo
Oil yield (%)	31.19[a]	26.87[a]	44.90[a]	44.16[a]
Colour	Pale-yellow	Pale-yellow	Light-yellow	Light-yellow
Odour	Pleasant intense	Pleasant intense	Pleasant intense	Pleasant intense

Values represent means of triplicate determinations; values with the same alphabet indicate no significant difference $p<0.05$.

B. Vitamin E Content

The results of the profile of vitamin E and the total vitamin content of the citrus seed oils are presented in Table 2. As shown in the table, grapefruit has significantly the highest amount of total tocopherols (20.74 %; $p < 0.0001$), followed by lime while lime, also has significantly the highest amount of tocotrienols followed by grapefruit. Alpha and gamma tocopherols were present in appreciable quantity in the four samples with grapefruit having the highest amount of alpha tocopherol while lime has the highest amount of gamma tocopherols. Likewise, grapefruit also significantly has the highest amount of vitamin E.

Table 2. Vitamin E profile of the investigated citrus seed oils.

Tocopherols (mg/100g)	Lime	Grapefruit	Tangerine	Tangelo
α tocopherols	10.59[b]	17.78[a]	5.374[d]	8.834[c]
γ tocopherols	2.38[b]	2.53[a]	1.072[d]	1.164[c]
β tocopherols	3.06×10^{-3}[c]	4.26×10^{-1}[a]	2.746×10^{-4}[d]	1.284×10^{-1}[b]
δ tocopherols	3.50×10^{-3}[a]	5.08×10^{-4}[b]	3.050×10^{-4}[d]	3.566×10^{-4}[c]
Total	12.98[b]	20.74[a]	6.45[d]	10.13[c]
Tocotrienols				
α tocotrienols	2.71×10^{-5}[d]	1.37[a]	1.362×10^{-1}[b]	1.217×10^{-1}[c]
γ tocotrienols	7.22[a]	2.37[b]	6.932×10^{-1}[c]	2.795×10^{-1}[d]
β tocotrienols	2.51×10^{-5}[c]	3.59×10^{-5}[b]	3.673×10^{-5}[a]	2.083×10^{-5}[d]
δ tocotrienols	2.49×10^{-5}[a]	1.21×10^{-5}[b]	1.204×10^{-5}[b]	1.551×10^{-6}[c]
Total	7.22[a]	3.74[b]	0.83[c]	0.40[d]
Total Vitamin E	20.2[b]	24.48[a]	7.28[d]	10.53[c]

Values represent means of triplicate determinations; values with different alphabet in a row indicate significant difference $p< 0.05$.

C. Phenolic Compound

Fifteen phenolic compounds were detected in all samples with gallic acid present in appreciable amount in the samples as shown in Table 3. This was followed by chlorogenic acid in grapefruit. Also, grapefruit has significantly higher amount of phenolic compound followed by lime.

Table 3. Phenolic compounds profile of the citrus seed oils.

Phenolic compounds (mg/100g)	Lime	Grapefruit	Tangerine	Tangelo
Salicylic Acid	1.943×10^{-3c}	5.814×10^{-3a}	4.829×10^{-5d}	4.254×10^{-3b}
Gentisic Acid	1.632×10^{-1b}	2.908×10^{-1a}	6.779×10^{-2c}	4.544×10^{-2d}
Protocatechuic acid	2.057×10^{-1d}	3.506×10^{-1b}	3.552×10^{-1a}	2.528×10^{-1c}
O – coumaric	1.196×10^{-3c}	1.654×10^{-3b}	2.242×10^{-3a}	4.342×10^{-4d}
Vanillic acid	8.328×10^{-1a}	5.929×10^{-1b}	4.977×10^{-1d}	5.297×10^{-1c}
p- hydroxybenzoic	6.653×10^{-2c}	7.303×10^{-2b}	9.957×10^{-2a}	6.459×10^{-2d}
Cinnamic acid	1.006×10^{-3c}	1.027×10^{-3b}	7.204×10^{-4d}	1.410×10^{-3a}
Gallic acid	1.518^{b}	2.339^{a}	1.395^{c}	1.213^{d}
Caffeic acid	3.007×10^{-1d}	8.462×10^{-1a}	3.195×10^{-1c}	3.643×10^{-1b}
Ferulic acid	3.734×10^{-2d}	6.010×10^{-2a}	4.369×10^{-2c}	4.673×10^{-2b}
Syringic acid	3.477×10^{-2d}	4.700×10^{-2c}	5.139×10^{-2b}	6.001×10^{-2a}
Ellagic acid	3.172×10^{-1d}	3.357×10^{-1c}	4.640×10^{-1b}	4.902×10^{-1a}
Piperic acid	3.289×10^{-1a}	1.950×10^{-5b}	4.563×10^{-6d}	7.140×10^{-6c}
Sinapinic acid	7.433×10^{-5d}	4.732×10^{-4a}	8.147×10^{-5c}	1.106×10^{-4b}
Chlorogenic acid	8.708×10^{-1b}	1.067^{a}	6.390×10^{-1d}	6.636×10^{-1c}
Total	**4.680^{b}**	**6.011^{a}**	**3.936^{c}**	**3.737^{d}**

Values represent means of triplicate determinations; values with different alphabet in a row indicate significant difference $p < 0.05$.

D. Antioxidant Activity

All citrus oil had high DPPH scavenging abilities which ranged between 69.89 – 89.76%. The highest scavenging ability was observed at concentration of 200 µl/ml, as shown in Figure 1 with lime having the highest radical scavenging ability at the specified concentration. Overall, there was no significant difference in the DPPH scavenging abilities of the seed oils.

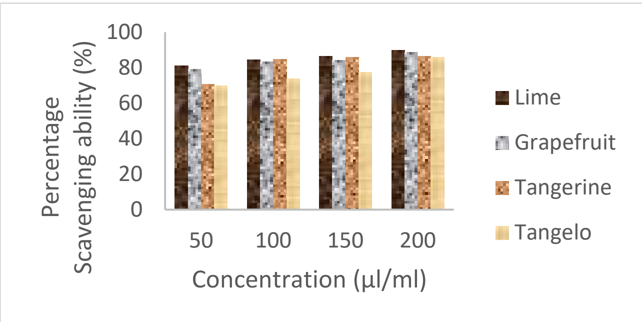

Figure 1. DPPH radical scavenging ability of the citrus seed oils

Likewise, all the samples had significantly good ferric reducing abilities in the following decreasing order grapefruit > lime > Tangelo > Tangerine as shown in Figure 2.

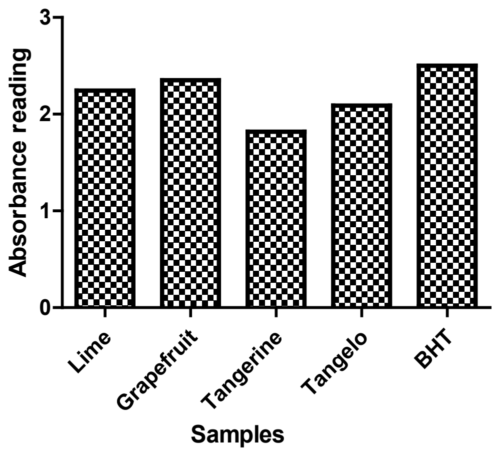

Figure 2. The ferric reducing ability of the citrus seed oils and BHT.

E. Correlation Between the Total Vitamin E Contents, Phenolic Compounds, and Antioxidant Activity of the Seed Oils

There was a strong positive correlation between the total vitamin E content and the reducing ability of the oils and phenolic compounds and reducing ability of the seed oil (R2 = 0.945 and 0.787, respectively). Also, between the radical scavenging ability and the total tocotrienols of the seed oils (R2= 0.830) as presented in Table 4a. In addition, some of the vitamin E contents and phenolic compounds had strong correlation with the antioxidant activity of the seed oils as presented in Table 4b.

Table 4 (a). Pearson correlation between total vitamin E, phenolic compounds, antioxidant activity, total tocopherol and total tocotrienols of citrus seed oils.

	α tocopherols	γ tocopherols	δ tocotrienols	δ tocotrienols	Vanillic acid	Gallic acid	Caffeic acid	Chlorogenic acid	Sinapinic acid
DPPH	0.385	0.765	0.769	0.918	0.677	0.554	0.229	0.644	0.251
FRAP	0.905	0.892	0.528	0.289	0.571	0.676	0.634	0.884	0.644

Table 4 (b). Pearson Correlation between some of the classes of vitamin E, phenolic profiles and antioxidant activity of the citrus seed oils

	Total vitamin E	DPPH	Phenolic compounds	FRAP	Total Tocopherols	Total Tocotrienols
Total Vitamin E		0.649	0.915	0.945	0.939	0.750
DPPH	0.649		0.638	0.394	0.432	0.830
Phenolic compounds	0.915	0.638		0.787	0.946	0.520
FRAP	0.945	0.394	0.787		0.916	0.653
Total Tocopherols	0.939	0.432	0.946	0.916		0.478
Total Tocotrienols	0.750	0.830	0.520	0.653	0.478	

IV. DISCUSSION

All the seeds had good percentage oil yield showing that the citrus species could be good sources of oils for industrial purposes. Thus, confirming the result of some other authors on the percentage oil yield of the citrus seed (Anwar *et al.*, 2008; Malacrida *et al.*, 2012; Ozcan *et al.*, 2022). The pleasant odour of the oils showed that they could be used as flavouring agents in the food, cosmetics, and pharmaceutical industries and this further highlights the importance of these oils and their applicability in the industries.

Vitamin E is a major lipid – soluble antioxidant found in the cell antioxidant defence system. Vitamin E inhibits free radicals by donating the hydrogen atom from the hydroxyl (-OH) group on the ring structure to the free radicals, thus making them to become unreactive (Ha & Lean, 1997). After donating the hydrogen atom, the vitamin E itself becomes a relatively unreactive free radical because the unpaired electron on the oxygen atom is usually delocalised into the aromatic ring structure thereby increasing its stability (Niki, 2007). The availability of all the tocopherols in the seed oils also showed the beneficial effects of the seed oils. Research has proven that a mixture of tocopherols has a stronger inhibitory effect on lipid peroxidation induced in human erythrocytes compared to alpha-tocopherol alone (Howard *et al.*, 2011) and that when present even in small quantity it exerts its maximum protective effects of the cell membrane against free radical attacks thereby protecting the cell from occurrence of diseases. Owing to the beneficial effects of these vitamin Es, the regular consumption of food sources with averagely high concentration is highly recommended. Because it has been found that deficiency of Vitamin E in some cases could lead to anaemia due to the oxidative damage to the red blood cells, retinopathy, and the impairment of the immune response (Li *et al.*, 1999; Rathore *et al.*, 2011). Moreover, it could result in blindness, heart disease, permanent nerve damage and impaired thinking if untreated (Li *et al.*, 1999).

The presence of gallic, protocatechuic, vanillic, caffeic, ellagic and chlorogenic acids in appreciable quantity in these seed oils is worth noting as this is an indication that the seed oils could be good sources of these phenolic compounds which have been found to be of great health benefits. Protocatechuic acid (PCA) has been found to have beneficial effects on osteoblast and osteoclast cells in vitro (Jang *et al.*, 2018) hence, useful for bone health. In addition, consuming caffeic – rich foods has been found to be of help in preventing formation of nitrosamines and nitrosamides, which are the main inducers of carcinogenesis. (Damasceno *et al.*, 2017; Touaibia *et al.*, 2011). Vanillic acid has been found to have in vitro antioxidant mechanisms, they have the ability to scavenge free radicals, they also have good reducing power and help to inhibit lipid peroxidation (Calixto-Campos *et al.*, 2015), and this was shown in their moderately high correction coefficient (Table 4b) thus showing their antioxidant power. These further highlights the health benefits and importance of the investigated seed oils. Therefore, these fruits could be good sources of these essential bioactive compounds.

The results of the vitamin E profile and phenolic compounds profile presented in this work are similar to the reports of other authors who have worked on some citrus seeds (Sir Elkhatim *et al.*, 2018; Xi *et al.*, 2015) this further highlights the importance of these citrus seed oils.

The mechanism of action of antioxidants is to help to stimulate and sustain cellular defence mechanisms and thus helping to prevent cellular components against oxidative damage that could be caused by free radicals. This has led to the search for natural antioxidants that could be obtained from food sources as this will help to boost the defence and the immune system of the body without any severe adverse effects.

The citrus seed oils showed very high DPPH radical scavenging abilities and good ferric reducing abilities, thus confirming that the seed oils have good antioxidant ability as reported by some other authors (Jorge *et al.*, 2016; Malacrida *et al.*, 2012; Ozcan *et al.*, 2022). There has been increasing interest in search for naturally occurring antioxidant for food and pharmaceutical products because of the possibility of toxicity from synthetic antioxidants thus, oil from these citrus seeds could be of great value in the food industries owing to the fact that the fruits are edible and by extension the oils extracted from the seeds are also useful therefore, helping to alleviate the problem of ageing and various diseases caused by free radicals and oxidative cellular activities as the global diets is moving towards Western pattern diet. In addition, by virtue of their antioxidant activities, they may also help to boost the immune system because they have been found to contain averagely high amount of vitamin C (Najwa & Azrina, 2017). Moreover, these oils could be used in the cosmetics industries as anti-aging products in creams and other cosmetic products as well as flavouring agents in food and pharmaceutical industries because of their characteristic pleasant smells.

The observed relatively good DPPH radical scavenging ability of lime and grapefruit oils may be due to the high amount of vitamin E content present in the samples. Vitamin E has been found to function as a peroxyl radical scavenger that terminates chain reactions (Niki, 2014) and thus helps to protect against degenerative processes that can cause some diseases like cancer, cardiovascular heart diseases, Alzheimer's, and also help to boost the immune system (Rizvi *et al.*, 2014; Schwenke, 2002). The various classes of tocopherols have been found to have relatively good hydrogen atom donating ability, and this also increases the efficiency of the antioxidant activity (Traber & Atkinson, 2007). This has also been shown by the observed relatively high correlation coefficient of tocotrienols and tocopherols (Table 4b).

Phenolic compounds have been found to be linked with antioxidant activities of compounds because of their redox properties like degrading peroxides, quenching oxygen and scavenging of free radicals, which help to boost the antioxidant power of compounds. They also have the ability to bind and modify the structures of some other multi-subunit proteins and alter their biological activities (Rohn *et al.*, 2002; Suryaprakash *et al.*, 2000; Yeh & Yen, 2003). Thus, the observed antioxidant activity of these oils may be linked to the high quantity of phenolic compounds present in the oils. This was also confirmed by the correlation coefficient between the phenolic compounds and the antioxidant activity of the oils (Table 4a).

The high correlation coefficient observed between total vitamin E, phenolic compounds, tocopherols, tocotrienols and antioxidant activities of the seed oils has also shown that there is a strong relationship between the Vitamin E contents, phenolic compound and antioxidant activity of the seed oils. This research also corroborates the finding of some other authors on the relationship that exist between antioxidant activity, Phenolic compounds and Vitamin E contents of different samples (Shan *et al.*, 2019; Sir Elkhatim *et al.*, 2018; Zhao *et al.*, 2006).

V. CONCLUSION

The citrus seeds had good oil yield showing that these seeds could be good sources of oil and thus could be of great use to the industry. In addition, the seed oils have considerably high amount of vitamin E content and phenolic compounds, which have been found to have antioxidant property thus confirming that these seed oils could be of good nutritional benefits. All the seed oils have good antioxidant activities, which showed that these oils could be used in food, pharmaceutical and cosmetics industries thus, could be useful in helping to reduce the problem associated with the generation of free radicals as the global diets system is tending towards Western pattern instead of being considered as waste. The correlation between the Vitamin E, phenolic compounds and the antioxidant activities of the seed oils also showed that the presence of these compounds help to boost the antioxidant ability of the seed oils.

VI. CONFLICT OF INTEREST

The authors declare no conflicts of interest.

VII. REFERENCES

Ahsan, H, Ahad, A & Siddiqui, WA 2015, 'A review of characterization of tocotrienols from plant oils and foods', Journal of Chemical Biology, vol. 8, no. 2, pp. 45–59.

Anwar, F, Naseer, R, Bhanger, MI, Ashraf, S, Talpur, FN & Aladedunye, FA 2008, 'Physico-chemical characteristics of citrus seeds and seed oils from Pakistan', Journal of the American Oil Chemists' Society, vol. 85, no. 4, pp. 321–330.

Ayoola, GA, Johnson, OO, Adelowotan, T, Aibinu, IE, Adenipekun, E, Adepoju-Bello, AA, Coker, HAB & Odugbemi, TO 2008, 'Evaluation of the chemical constituents and the antimicrobial activity of the volatile oil of *Citrus reticulata* fruit (Tangerine fruit peel) from South West Nigeria', African Journal of Biotechnology, vol. 7, no. 3, pp. 2227 - 2231.

Barja, G 2014, 'The mitochondrial free radical theory of aging', Progress in Molecular Biology and Translational Science, vol. 127, pp. 1–27.

Bunea, A, Rugina, OD, Pintea, AM, Sconta, Z, Bunea, CI & Socaciu, C 2011, 'Comparative polyphenolic content and antioxidant activities of some wild and cultivated blueberries from Romania', Notulae Botanicae Horti Agrobotanici Cluj-Napoca, vol. 39, no. 2, pp. 70–76.

Calixto-Campos, C, Carvalho, TT, Hohmann, MS, Pinho-Ribeiro, FA, Fattori, V, Manchope, MF, Zarpelon, AC, Baracat, MM, Georgetti, SR & Casagrande, R 2015, 'Vanillic acid inhibits inflammatory pain by inhibiting neutrophil recruitment, oxidative stress, cytokine production, and NFκB activation in mice', Journal of natural products, vol. 78, no. 8, pp. 1799–1808.

Damasceno, SS, Dantas, BB, Ribeiro-Filho, J, Araújo, AM & da Costa, GM 2017, 'Chemical properties of caffeic and ferulic acids in biological system: implications in cancer therapy A review', Current Pharmaceutical Design, vol. 23, no. 20, pp. 3015–3023.

Du, M & Ahn, DU 2002, 'Simultaneous analysis of tocopherols, cholesterol, and phytosterols using gas chromatography', Journal of Food Science, vol. 67, no. 5, pp. 1696–1700.

Gyamfi, MA, Yonamine, M & Aniya, Y 1999, 'Free-radical scavenging action of medicinal herbs from Ghana: *Thonningia sanguinea* on experimentally-induced liver injuries', General Pharmacology: The Vascular System, vol, 32, no. 6, pp. 661–667.

Ha, TKK & Lean, MEJ 1997, 'Vitamin E, in: Principles of Medical Biology', Elsevier, vol. 8, pp. 951–963.

Howard, AC, McNeil, AK & McNeil, PL 2011, 'Promotion of plasma membrane repair by vitamin E', Nature Communications, vol. 2, no.1, pp. 1–8.

Jang, SA, Song, HS, Kwon, JE, Baek, HJ, Koo, HJ, Sohn, EH, Lee, SR & Kang, SC 2018, 'Protocatechuic acid attenuates trabecular bone loss in ovariectomized mice', Oxidative Medicine and Cellular Longevity 2018.

Javed, S, Javaid, A, Nawaz, S, Saeed, MK, Mahmood, Z, Siddiqui, SZ & Ahmad, R 2014, 'Phytochemistry, GC-MS analysis, antioxidant and antimicrobial potential of essential oil from five citrus species', Journal of Agricultural Science, vol. 6, no. 3, pp. 201.

Jorge, N, Silva, AC & da Aranha, CPM 2016, 'Antioxidant activity of oils extracted from orange (*Citrus sinensis*) seeds', Anais da Academia Brasileira de Ciências, vol. 88, no. 2, pp. 951–958.

Li, D, Saldeen, T, Romeo, F & Mehta, JL 1999, 'Relative effects of α-and γ-tocopherol on low-density lipoprotein oxidation and superoxide dismutase and nitric oxide synthase activity and protein expression in rats', Journal of Cardiovascular Pharmacology and Therapeutics, vol. 4, no. 4, pp. 219–226.

Malacrida, CR, Kimura, M & Jorge, N 2012, 'Phytochemicals and antioxidant activity of citrus seed oils', Food Science and Technology Research, vol. 18, no. 3, pp. 399–404.

Mathur, A, Verma, SK, Purohit, R, Gupta, V, Dua, VK, Prasad, G, Mathur, D, Singh, SK & Singh, S 2011, 'Evaluation of in vitro antimicrobial and antioxidant activities of peel and pulp of some citrus fruits', Journal of Biotechnology and Biotherapeutics, vol. 1, no. 2, pp. 1–17.

Najwa, FR & Azrina, A 2017, 'Comparison of vitamin C content in citrus fruits by titration and high-performance liquid chromatography (HPLC) methods', International Food Research Journal, vol. 24, no. 2, pp. 726.

Niki, E 2014, 'Role of vitamin E as a lipid-soluble peroxyl radical scavenger: in vitro and in vivo evidence', Free Radical Biology and Medicine, vol. 66, pp. 3–12.

Niki, E 2007, 'Tocopherylquinone and tocopherylhydroquinone', Redox Report, vol. 12, no. 5, pp. 204–210.

Oboh, G & Ademosun, AO 2012, 'Characterization of the antioxidant properties of phenolic extracts from some citrus peels', Journal of Food Science and Technology, vol. 49, no. 6, pp. 729–736.

Olatunya, AM 2021, 'Bioactive components of two species of locally grown nuts: Their potential health benefits and implications for healthy living', Bioactive Compounds in Health and Disease, vol. 4, no. 12, pp. 301–310.

Olatunya, AM & Akintayo, ET 2017, 'Evaluation of the effect of drying on the chemical composition and antioxidant activity of the essential oil of peels from three species of citrus group', International Food Research Journal, vol. 24, no. 5, pp. 1991–1997.

Olatunya, AM, Omojola, A, Akinpelu, K & Akintayo, ET 2019, 'Vitamin E, Phospholipid, and Phytosterol Contents of *Parkia biglobosa* and *Citrullus colocynthis* Seeds and Their Potential Applications to Human Health', Preventive Nutrition and Food Science, vol. 24, no. 3, pp. 338–343.

Oyaizu, M 1986, 'Studies on products of browning reaction--antioxidative activities of products of browning reaction prepared from glucosamine', Japanese Journal of Nutrition, vol. 44, no. 6, pp. 307–315.

Ozcan, MM, Ozturk, O & Lemiasheuski, V 2022, 'Quality Properties, Fatty Acid Composition, and Mineral Contents of Some Citrus Seeds and Oils Extracted by Solvent Extraction', Erwerbs-Obstbau, Springer UK.

Provan, GJ, Scobbie, L & Chesson, A 1994, 'Determination of phenolic acids in plant cell walls by microwave digestion', Journal of the Science of Food and Agriculture, vol. 64, no. 1, pp. 63–65.

Rathore, G, Suthar, M, Pareek, A & Gupta, R 2011, 'Nutritional antioxidants: A battle for better health', Journal of Natural Pharmaceuticals, vol. 2, no. 1, pp. 2–2.

Redfern, J, Kinninmonth, M, Burdass, D & Verran, J 2014, 'Using soxhlet ethanol extraction to produce and test plant material (essential oils) for their antimicrobial properties', Journal of Microbiology & Biology Education, vol. 15, no. 1, pp. 45–46.

Rizvi, S, Raza, ST, Ahmed, F, Ahmad, A, Abbas, S & Mahdi, F 2014, 'The role of vitamin E in human health and some diseases', Sultan Qaboos University Medical Journal, vol. 14, no. 2, p. e157.

Rohn, S, Rawel, HM & Kroll, J 2002, 'Inhibitory effects of plant phenols on the activity of selected enzymes', Journal of Agricultural and Food Chemistry, vol. 50 no. 12, pp. 3566–3571.

Rudzińska, M, Hassanein, MM, Abdel–Razek, AG, Ratusz, K & Siger, A 2016, 'Blends of rapeseed oil with black cumin and rice bran oils for increasing the oxidative stability', Journal of Food Science and Technology, vol. 53, no. 2, pp. 1055–1062.

Sales, JM & Resurreccion, AVA 2010, 'Phenolic profile, antioxidants, and sensory acceptance of bioactive-enhanced peanuts using ultrasound and UV', Food Chemistry, vol. 122, no. 3, pp. 795–803.

Schwenke, DC 2002, 'Does lack of tocopherols and tocotrienols put women at increased risk of breast cancer', The Journal of Nutritional Biochemistry, vol. 13, no.1, pp. 2–20.

Shan, S, Huang, X, Shah, MH & Abbasi, AM 2019, 'Evaluation of polyphenolics content and antioxidant activity in edible wild fruits', BioMed Research International, vol. 2019.

Sir Elkhatim, KA, Elagib, RA & Hassan, AB 2018, 'Content of phenolic compounds and vitamin C and antioxidant activity in wasted parts of Sudanese citrus fruits', Food Science and Nutrition, vol. 6, no. 5, pp. 1214–1219.

Suryaprakash, P, Kumar, RP & Prakash, V 2000, 'Thermodynamics of interaction of caffeic acid and quinic acid with multisubunit proteins', International Journal of Biological Macromolecules, vol. 27, no. 3, pp. 219–228.

Touaibia, M, Jean-Francois, J & Doiron, J 2011, 'Caffeic Acid, a versatile pharmacophore: an overview', Mini reviews in Medicinal Chemistry, vol. 11, no. 8, pp. 695–713.

Traber, MG & Atkinson, J 2007, 'Vitamin E, antioxidant and nothing more', Free Radical Biology and Medicine, vol. 43, no. 1, pp. 4–15.

Xi, W, Zhang, G, Jiang, D & Zhou, Z 2015, 'Phenolic compositions and antioxidant activities of grapefruit (*Citrus paradisi* Macfadyen) varieties cultivated in China,' International Journal of Food Sciences and Nutrition, vol. 66, no. 8, pp. 858–866.

Yang, X, Zhang, D, Song, L, Xu, Q, Li, H & Xu, H 2017, 'Chemical profile and antioxidant activity of the oil from peony seeds (*Paeonia suffruticosa* Andr.)', Oxidative Medicine and Cellular Longevity 2017.

Yang, XN & Kang, SC 2013, 'Chemical composition, antioxidant and antibacterial activities of essential oil from Korean *Citrus unshiu* peel', Journal of Agricultural Chemistry and Environment, vol. 2, no. 3(2013).

Yeh, CT & Yen, GC 2003, 'Effects of phenolic acids on human phenolsulfotransferases in relation to their antioxidant activity', Journal of Agricultural and Food Chemistry, vol. 51, no. 5, pp. 1474–1479.

Zhao, H, Dong, J, Lu, J, Chen, J, Li, Y, Shan, L, Lin, Y, Fan, W & Gu, G 2006, 'Effects of extraction solvent mixtures on antioxidant activity evaluation and their extraction capacity and selectivity for free phenolic compounds in barley (*Hordeum vulgare* L.)', Journal of Agricultural and Food Chemistry, vol. 54, no. 19, pp. 7277–7286.