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COMPARATIVE EVALUATION OF THE *In Vitro* ANTIMICROBIAL AND ANTIOXIDANT POTENTIAL OF *Telfairia occidentalis* SEED ESSENTIAL OIL AND CRUDE EXTRACT

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ABSTRACT

Antimicrobial resistance is a prevalent health challenge affecting human, animal, and environmental health, while oxidative stress contributes to an increased susceptibility of humans to infections due to an increased free radical activity, thus requiring urgent alternative solutions. The present work, therefore, compares the therapeutic potential of the crude extract (CE) and essential oil (EO) of *Telfaria occidentalis* seed. Oil extraction was achieved by steam distillation, and crude extract by maceration. GC-MS analysis revealed the chemical composition of the oil. Agar-well diffusion was used for bioassay screening, while FRAP, DPPH and NO scavenging were used for antioxidant activity. Antimicrobial evaluation against five bacterial strains demonstrated that the CE exhibited stronger antimicrobial activity than the oil, with inhibition zones (IZ) (mm) of 20.00±1.11: *K. pneumonia*, 21.00±1.26: *E. coli*, 18.00±1.23: *S. aureus*, 23.00±1.02 *P. aeruginosa*, and 24.00±1.24: *S. typhi*, while the essential oil had IZ of 17.00±1.24, 16.00±1.16, 12.00±1.11, 18.00±1.12, and 15.00±1.32 against *K. pneumoniae, E. coli*, *S. aureus, P. aeruginosa,* and *S. typhi,* respectively. However, the EO demonstrated superior NO scavenging (IC_{50}: CE: 28.32 % vs EO: 30.25), DPPH scavenging (EO: 62.22 µg/mL vs. CE: 66.22 µg/mL) and FRAP activities (EO: 3.42 µg/mL vs CE: 2.10 µg/mL) than the CE. These findings indicate that the CE has better antimicrobial potential than the volatile oils, while the oil displayed better antioxidant activity across all assays employed. To conclude, the crude extract showed promise as a potential source of lead compounds for developing treatments against multidrug-resistant pathogens. In addition, the strong antioxidant activity of the essential oil suggests that it could serve as a natural agent for mitigating oxidative stress-related damage in pharmaceutical, nutraceutical, and food preservation applications.

Keywords: *Telfairia occidentalis*, Antimicrobial, Antioxidant, GC-MS, Crude extract, Essential oil

INTRODUCTION

Antimicrobial resistance is a prevalent health challenge affecting human, animal, and environmental health, as well as the global economy and development (WHO, 2022), requiring urgent alternative solutions. Among the underlying factors contributing to an increased susceptibility of man to infections is oxidative stress, this is due to increase in the activities of free radicals around the world, hence contributing to diseases such as diabetes, immunosuppression and neurodegeneration (Garcia-Llorens, et al., 2025), and as such poses a global health risk. This therefore reinforces the need for alternative agents possessing antimicrobial as well as antioxidant properties, especially from natural sources.

Plants continue to be invaluable sources of bioactive compounds otherwise referred to phytochemicals. These plant chemicals have displayed significant biological activities such as antimicrobial activities against antibiotic resistant bacteria (Akinsipo *et al.,* 2026). Their different parts (leaves, stems, roots, seeds, flowers, as well as bark) serve as natural reserves of bioactive compounds (secondary metabolites) with therapeutic and nutraceutical potentials (Osibote *et al.,* 2020). These potentials have been extensively explored by researchers over the years, and efforts have been made to characterize the different phytochemical compounds responsible for the various biological activities.

Telfaria occidentalis (*T. occidentalis*), is a tropical vine common in West Africa, especially Nigeria and one of such plants with therapeutic potential. Its leaf is highly valued as a stable food whose leaf juice is a traditional blood booster (Ojimelukwe, 2022) while its seeds have been reported to possess antioxidant (Eseyin *et al.,* 2018), antidiabetic (Daramola et al., 2016; Teugwa et al., 2013), cytotoxic, and anti-inflammatory activities (Ojimelukwe, 2022). Plant-derived compounds contain complex mixtures of compounds, and *T. occidentalis* is a typical example of a medicinal plant which is readily available and is a potential source of natural compounds capable of overcoming or complementing conventional medicines in the fight against antimicrobial resistance as well as oxidative stress.

It is commonly grown for its nutrient-rich leaves and seeds (Ali *et al.,* 2024). Its leaf is highly valued as a stable food, its use as a source of iron/blood booster when experiencing feelings of dizziness/lightheadedness is commonplace among Nigerians, and several reports have been documented on its blood-boosting potential in Wistar rats (Ojimelukwe, 2022).

Differences in the extraction technique, polarity and volatility, however, affect the chemical composition of crude extract and essential oil and are perceived to influence their biological activity (Sun, et al., 2025; Ćujić et al., 2016). Despite the numerous reports on the plant of study, a comparative assessment of the biological activity between the seed crude extract and its oil remains unexplored. It is therefore hypothesised that *T. occidentalis* seed essential oil and its crude methanolic extract may possess significant antimicrobial and antioxidant activities with different efficacy results from variation in their chemical composition. This study thus aims to evaluate and compare the antimicrobial and antioxidant potential of *T. occidentalis* seed essential oil and

crude methanolic extract. The findings of the research are expected to contribute to the growing body of knowledge on plant-based bioactive compounds and contribute to the global search for natural antioxidants and antimicrobial agents.

MATERIALS AND METHODS

Plant Collection and Preparation

Fresh and healthy *T. occidentalis* plant (Figure 1) was collected from Epe Market in Epe LGA of Lagos State, South West, Nigeria in March, 2025. Identification and authentication were done at the Herbarium of the Department of Botany, Lagos State University, Ojo Campus by Dr. Oluwa O. K. Voucher specimen was deposited and a voucher number (LSH-001264) was assigned. The fresh plant was cleaned of debris, and air-dried at room temperature.

Figure 1: Pod of *T. occidentalis*

Plant extraction

T. occidentalis seeds were air dried under shade for 3 days. The total mass of the pulverized seed obtained was 326g this was divided into two equal parts. 163g were loaded into a Clevenger typed steam distillation setup and distilled for 3 hours after which the volatile oil was collected, dried over anhydrous sodium sulfate and filtered to obtain 1.65 g of the oil. Steam distillation is an established method which has been widely used over the years for EO extraction due to its simplicity (Machado et al., 2022, Povh et al., 2001) and its ability to isolate volatile as well as thermally stable essential oil components while limiting thermal degradation, hence making it a method of choice.

The crude extract was obtained by maceration of the second portion of the 163g of pulverized *T. occidentalis* seeds. This was soaked in 2 litres of methanol for 72 hours, with occasional shaking. Methanol was the choice solvent because it is a solvent capable of holistic extraction of phytochemicals due to its high polarity. This method is a simple and reproducible extraction approach which prevents thermal degradation of heat-sensitive compounds because it is mostly carried out at room temperature. After 72h the extract was filtered and dried with a rotatory evaporator at 40 °C and a yield of 6.85 g was obtained.Both extracts were collected and stored in separate amber glass vials and refrigerated to prevent photo degradation until further analysis.

Analysis of the extracted oil

The essential oil of *T. occidentalis* was analyzed following established Gas Chromatography Mass Spectrometry (GCMS) procedure with minor modifications. The GCMS analysis was performed on a Perkin Elmer Turbo Mass Clarus 600 Instrument at 70 eV ionization energy with a mass range of 40-500 amu. The oven temperature was programmed from 50 °C to 250 °C at a 5 °C/min dynamic rate and remained for 15 min at 250 °C, employing an Elite-5 column (5 % phenyl and 95 % dimethylpolysiloxane) of 30 m length, 0.25 mm internal diameter and 0.25 µm film thickness (Pekin Elmer, USA). Helium (1 mL/min) was used as a carrier gas. The initial oven temperature was 60 °C/ min, remained at 240 °C for 6 min, and then continued to increase to 250 °C at the rate of 10 °/min. with a final stage of 10 min at 250 °C. The sample (0.1 µL) was injected in a splitless mode. Component identification was accomplished by comparison of the retention indices (RI) of the GC peaks with those obtained using saturated n-alkanes (C8-C30) (Aldrich, USA), those reported in the literature and by comparison of the peaks with those reported in the literature and stored in the NIST library (Njoku et al, 2021, Koenig et al., 1998). The retention index are provided in the result section.

Antimicrobial Assay

The *invitro* antimicrobial activity of the extracted oil and the crude methanol extract of *T. occidentalis* was carried out against five bacterial strains: *K. pneumonia, E. coli, P. aeruginosa, S. typhi, and S. aureus* using the agar well diffusion method (Osinubi *et al*., 2023) with minor modifications. These bacterial strains are clinically relevant strains known to display multidrug resistance to conventional antibiotics. Gentamicin (2 mg/mL) was the positive control, while hexane was the negative control to ensure that the activities were not solvent-induced. Nutrient agar plates were seeded with 0.1 mL of an overnight culture of each bacterial strain (equiv. to 10^7-10^8 CFU/mL). The seeded plates were allowed to set, and a standard cork borer (diameter: 7 mm) was used to cut uniform holes on the surface of the agar. 10 µL each of the essential oil and the crude extract (2 mg/mL) was used. Each extract was introduced into the wells and set in an incubator at 30°C for 24 h. After this, the clear area around each well was measured indicating the zone of inhibition (mm).

Antioxidant Assay

To comprehensively evaluate the antioxidant capacity of the extracts, three complementary assays were employed, viz.: DPPH radical Scavenging, FRAP and nitric oxide scavenging.

DPPH free radical scavenging assay

The antioxidant properties of the essential oil were evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay, with minor modification (Osinubi *et al.,* 2024, Odusina et al., 2023). DPPH solution (0.1 mM, methanol) was freshly prepared, and the solution (1 mL) was added to 1 mL of the extracted *T. occidentalis* essential oil and crude extract separately. Each mixture was shaken together and incubated for 30 min. After incubation, UV-Vis analysis

was run at a wavelength of 517 nm. Ascorbic acid served as the positive control.
Percentage scavenging activity was calculated using equation 1

DPPH Scavenging effect (%) = $[(A_0 - A_1)/ A_0] * 100$ (1)

Where A_0 = absorbance of control and A_1 = absorbance of respective extract (Crude and Oil)
The IC_{50} value was defined as the concentration of the extract required to achieve 50% inhibition of DPPH radical activity

Ferric Reducing Antioxidant Power (FRAP) Assay
The FRAP assay was carried out following (Fernandes et al., 2016) protocol. Acetate buffer (300 mM, pH 3.6), TPTZ solution (10 mM in 40 mM HCl), and ferric chloride solution (20 mM) were mixed in a ratio of 10:1:1 (v/v/v) to obtain freshly prepared FRAP reagent.
The *T. occidentalis* extracts were mixed with the FRAP reagent and incubated for 30 min at 37 °C after which absorbance was measured at 593 nm on a UV-Vis Spectrophotometer. Gallic acid was used as positive control. The percentage FRAP Scavenging activity was determined using equation 2

FRAP Scavenging effect (%) =
$[(Ae - Ab)/ (Ac - Ab)] X 2$ (2)

Where A_b = Absorbance of blank reacted with water and A_e = Absorbance of respective extracts (Crude and Oil) A_c = Absorbance of positive control, reacted with ascorbic acid. Leftover reagents were discarded that is, all reagent used must be freshly prepared.

Nitric Oxide (NO) Scavenging Assay
The NO scavenging assay of *T. occidentalis* seed extracts was achieved following previously reported (Makhija et al., 2011) method with minor modification. NO radicals were generated from sodium nitroprusside. 1 mL of 10 mM sodium nitroprusside was mixed with I mL each of *T. occidentalis* CE and VO separately to give a concentration of 0.025 – 0.05 mg/mL in phosphate buffer. Each mixture was then incubated for 150 minutes at 25 °C. After incubation, 1 mL of the Griess reagent (1% sulfanilamide in 5 % phosphoric acid and 0.1 % *N*-(1-naphthyl) ethylenediamine dihydrochloride) was added to each sample. The resulting mixtures were analysed at 546 nm with a UV-Vis spectrophotometer. Ascorbic acid served as the positive control. Percentage inhibition of NO radical was obtained from equation 3.

Nitric Oxide scavenged (%) = $\left[\frac{A_{control} - A_{test}}{A_{control}}\right] * 100$ (3)

Where $A_{control}$ is the absorbance of the control and A_{test} is the absorbance of extract.

Data Analysis
All experiments were done in triplicate. Data analysis was achieved with Microsoft Excel 2010. Results are presented as mean ± standard deviation.

RESULTS AND DISCUSSION

Result of GCMS analysis
The result of GCMS analysis of *T. occidentalis* essential oil revealed the presence of 32 volatile compounds. The essential oil is found to be composed mainly of monoterpenes, sesquiterpenes and diterpenes. β-Elemene (-) (25.02 %), Humulene (20.42 %), Isocaryophyllene (17.65 %), Cyclofenchene (11.30 %), were the most prominent components of the oil, while others were obtained in small quantities (Table 1). β-Elemene, a sesquiterpene and the most abundant element in *T. occidentalis* oil are known anticancer/antitumor agent identified as an active ingredient extracted from rhizomes of *Curcuma wenyujin* (Bai et al., 2021). Its prominent abundance in *T. occidentalis* is indicative of the oil's potential application in drug development and application. Humulene, the second prominent compound reported to be a common component of essential oils applied in flavor and fragrance (Osinubi et al., 2025 Sarkic and Stappen, 2018; van Beek and Joulain, 2018) has been identified as a therapeutic agent known to display a synergistic interaction when in combination with other oil constituents (Kang *et al.,* 2022), thereby increasing the bioactivity of the essential oil.

Table 1: Chemical composition of the essential oil of *T. occidentalis*

Name	RI_{lit}	RI_{cal}	Area %
1R-α-Pinene	929	932	0.21
Cyclofenchene	886	882	11.31
o-Cymene	1025	1027	0.45
4,7-Methano-1H-indene, octahydro-	1078	1080	1.69
Limonene	1023	1026	0.81
p-Menth-8-ene, cis-	993	990	0.03
γ-Terpinene	1050	1048	1.41
Terpinolene	1079	1077	0.27
L-trans-Pinocarveol	1126	1129	0.36
Isoborneol	1159	1162	0.08
Terpinen-4-ol	1164	1162	0.87
β-Terpineol	1137	1138	4.43
α-Terpinyl acetate	1333	1336	0.29
Copaene	1376	1379	0.26
Valencene	1486	1484	0.34
Caryophyllene	1419	1414	7.68
Isocaryophyllene	1409	1406	17.65
β-Elemene, (-)-	1388	1389	25.02
cis-β-Farnesene	1447	1446	0.16
Humulene	1512	1510	20.42
α-Guaiene	1444	1448	1.86
Khusimene	1456	1470	0.43

cis-Muurola-4(15),5-diene	1454	1458	0.76
α-Muurolene	1494	1492	0.46
α-Patchoulene	1457	1459	0.04
cis-muurola-3,5-diene	1448	1446	0.10
Cadina-1(10),4-diene	1469	1469	0.87
Caryophyllene oxide	1574	1571	0.12
Isoaromadendrene epoxide	1590	1594	1.35
Caryophylla-4(12),8(13)-dien-5α-ol	1623	1620	0.14
trans-Z-α-Bisabolene epoxide	1586	1586	0.02
Cembrene	1934	1930	0.02

RIlit: retention index from literature, RIcal: calculated retention index

Antimicrobial Activity

The crude extract (CE) and the essential oil (EO) extracts of *T. occidentalis* seeds exhibited significant inhibitory effects against all tested microorganisms with varying degrees of potency (Table 2). The EO demonstrated moderate antibacterial activity, with zones of inhibition ranging from 12.00±1.11 mm against *S. aureus* to 18.00±1.12 mm against *P. aeruginosa*. The clinical implication of the finding is emphasized by the fact that P. *aeruginosa* is intrinsically resistant to many traditional antibiotics, which makes the treatment of infections caused by this pathogen more complicated (Schwartz et al., 2024; Giovagnorio et al., 2023). The CE on the other hand demonstrated stronger antibacterial activity, yielding inhibition zones from 18.00 ± 1.23 mm against *S. aureus* to 24.00 ± 1.24 mm against *S. typhi*. Its inhibitory effects on *others* differed only marginally from the reference drug except against *P.saeruginosa*, where the ZI was the same as that of the reference drug (23.00 ± 1.02 mm). These findings provide empirical support for the ethnomedicinal use of *T.occidentalis* plant in traditional Nigerian medicine.

The antimicrobial activity observed in the oil extract can be associated with its phytochemical composition, as determined by GC-MS analysis. The prevalence of the terpenes in the oil likely contributes to the observed effects. Despite the abundance of terpenes in the oil, the crude extract displayed superior inhibitory activity against the tested microorganisms, which is attributable to the broader spectrum of secondary metabolites.

Table 2: Antibacterial activity of the Crude extract and Essential Oils of *T. occidentalis* seed

Microorganisms	Diameters of zone of inhibition (mm)		
	Essential oil	Crude extract	Gentamicin
K. pneumoniae	17.00±1.24	20.00±1.11	22.00±0.14
E. coli	16.00±1.16	21.00±1.26	23.00±0.40
S. aureus	12.00±1.11	18.00±1.23	19.00±0.18
P. aeruginosa	18.00±1.12	23.00±1.02	23.00±1.12
S. typhi	15.00±1.32	24.00±1.24	25.00±1.44

Antioxidant Activity

The comparative antioxidant activity of the essential oil and the crude extract of *T. occidentalis* is presented in Table 3. FRAP, DPPH and NO scavenging activities were used to determine this property. By comparison, the EO displayed stronger DPPH scavenging activity than the CE because of its slightly lower IC_{50} value (IC_{50} values; EO: 62.22 ± 2.86 and CE: 66.22 ± 4.12 µg/mL). Relative to the standard used, both extracts had high DPPH scavenging activity. The high antioxidant activity displayed by these two agrees with the findings of other researchers who obtained significant DPPH scavenging activity in their study of *T. occidentalis* seed protein hydroxylate and peptide fractions (Ruth et al., 2023). Furthermore, the FRAP assay revealed that EO had better antioxidant activity than the CE (Table 3). EO exhibited a significantly higher reducing capacity (3.42 ± 0.02 µg/g) than CE (2.10 ± 0.02 µg/g). Suggesting that the predominant presence of the terpenes enhances the electron-donating ability of the oil relative to that of the crude extract, which is suspected to contain electron-donating potential-limiting components, hence hindering the electron-donating potential of the sample in its crude form. The compositional differences may account for the differences in antioxidant activity. This is supported by recent mechanistic studies that revealed that medicinal plants' antioxidant potential is a factor in their amount of hydroxyl groups that is phenolic and flavonoid constituents (Platzer, *et al*., 2022).

The EO had stronger nitric oxide scavenging activity (IC_{50}: 30.25 ± 0.36 %) than the CE (IC_{50}: 28.32 ± 1.10 %). This observation clearly shows the potential of its different components to interact with nitric oxide and neutralize its formation (Fatunmibi *et al.,* 2023). Relative to their respective +ve control values, both *T. occidentalis* preparations demonstrated moderate nitric oxide (NO) scavenging activity. These outcomes identify both *T. occidentalis* extracts as potential substances useful in combating inflammatory diseases resulting from prolonged exposure to nitric oxide radicals.

Table 3: DPPH, FRAP, and NO antioxidant assay of *T. occidentalis* seeds Essential oil and Crude extract

Antioxidant Assay of *T. occidentalis* seeds	CE	EO	AA (+ive control)
DPPH Assay (µg/mL)	66.22 ± 4.12	62.22 ± 2.86	70.24 ± 1.68
FRAP Assay (µg/g)	2.10 ± 0.02	3.42 ± 0.02	3.32 ± 0.02
NO (% Inhibition)	28.32 ± 1.10	30.25 ± 0.36	31.16 ± 0.32

CE: Crude extract, EO: Essential oil, AA: Ascorbic Acid.

CONCLUSION

This study demonstrated that both essential oil and crude extract from *T. occidentalis* seeds possess significant biological activity against clinically relevant pathogens, with the crude extract exhibiting superior inhibitory antimicrobial effects comparable to the standard antibiotics, while the essential oil extract displayed better antioxidant activity. The antioxidant capacity across multiple assay systems was substantial, although with varying potency depending on the specific method employed. These findings validate the traditional uses of *T. occidentalis* seeds in ethnomedicine for treating infections and inflammatory conditions common in West Africa. The results contribute to the growing body of research in biological activities of fluted pumpkin seeds and highlight its potential applications in pharmaceutical formulations.

Limitation of Study

This present research studied the effect of the essential oil and methanolic crude extracts on the zones of inhibition of some bacteria. It is however, limited by a lack of information on the minimum inhibitory concentration and minimum bactericidal concentration of the essential oil and the crude extract.

Future studies on the isolation and characterization of the active constituent responsible for these activities as well as *in vivo* evaluation, toxicity assessment and even molecular studies of their mechanism of action to further establish their safety and therapeutic relevance are recommended.

REFERENCES

Akinsipo, O. B., Osinubi, A. D., & Adebayo, B. P. (2026). Green Synthesis and Characterization of Zinc Oxide Nanoparticles Using *Euphorbia Lateriflora* Leaf Extract: Evaluation of Antimicrobial and Antioxidant Activities. *Fudma Journal of Sciences*, *10*(2), 45-54. https://doi.org/10.33003/fjs-2026-1002-4456

Ali, A. I, Dandago, M. A., & Ali, F. I. (2024). Food Applications of *Telfairia occidentalis* as a Functional Ingredient and Nanoencapsulation as a Promising Approach toward Enhancing Food Fortification. IntechOpen. doi: 10.5772/intechopen.111716 (Eds) Soto-Hernández, M., Aguirre-Hernández, E. and Palma-Tenango, M In: Phytochemicals in Agriculture and Food https://doi.org/10.5772/intechopen.111716

Bai, Z., Yao, C., Zhu, J., Xie, Y., Ye, X-Y., Bai, R., & Xie, T. (2021). Anti-tumor drug discovery based on natural product β-elemene: anti-tumor mechanisms and structural modification. *Molecules*, *26*(6), 1499. https://doi.org/10.3390/molecules26061499

Ćujić N., Šavikin K., Janković T., Pljevljakušić D., Zdunić G. & Ibrić S. (2016). Optimization of polyphenols extraction from dried chokeberry using maceration as traditional technique. Food Chem. 194, 135–142. https://doi.org/10.1016/j.foodchem.2015.08.008

Daramola O. O., Oyeyemi W. A., Odiase L. O., Olorunfemi A. A. (2016). Effects of methanol extract of *Telfairia occidentalis* seed on ovary antioxidant enzymes, serum hormone concentration and histology in wistar rats. *International Journal of Pharmacognosy and Phytochemical Research* 8:1245-9.

Eseyin, O. A., Daniel, A., Paul, T. S., Attih, E., Emmanuel, E., Ekarika, J., Munavvar Zubaid, A. S., Ashfaq, A., Afzal, S. & Ukeme, A. (2018). Phytochemical analysis and antioxidant activity of the seed of Telfairia occidentalis Hook (Cucurbitaceae). *Natural Product Research*. 32(4):444-447. https://doi.org/10.1080/14786419.2017.1308366

Fatunmibi O. O, Saint Njoku I, Asekun O. T. & Ogah J. O. (2023). Chemical composition, antioxidant and antimicrobial activity of the essential oil from the rhizome of Curcuma longa L. *Journal of Pharmacy and Allied Medicine.*; 1(1):27-33. https://doi.org/10.58985/jpam.2023.v01i01.04

Fernandes, R. P., Trindade, M. A., Tonin, F. G., Lima, C. G., Pugine, S. M., Munekata, P. E., Lorenzo, J. M., & de Melo, M. P. (2016). Evaluation of antioxidant capacity of 13 plant extracts by three different methods: cluster analyses applied for selection of the natural extracts with higher antioxidant capacity to replace synthetic antioxidant in lamb burgers. *Journal of Food Science and Technology*, 53(1), 451–460. https://doi.org/10.1007/s13197-015-1994-x

Garcia-Llorens, G., El Ouardi, M., & Valls-Belles, V. (2025). Oxidative stress fundamentals: Unraveling the pathophysiological role of redox imbalance in non-communicable diseases. *Applied Sciences*, *15*(18), 10191. https://doi.org/10.3390/app151810191

Giovagnorio, F., De Vito, A., Madeddu, G., Parisi, S. G., & Geremia, N. (2023). Resistance in *Pseudomonas aeruginosa*: A Narrative Review of Antibiogram Interpretation and Emerging Treatments. *Antibiotics (Basel, Switzerland)*, 12(11), 1621. https://doi.org/10.3390/antibiotics12111621

Kang, Y., Wang, X., Wei, X., Li, D., Gan, L., Jin, J.,Wu, R., Wu, P., Sheng, Z. Zhang, K., Goodin, S., Xu, X. & Zheng, X. (2022). Synergistic inhibitory effect of α-humulene and sclareol on human pancreatic cancer cells. *Journal of Functional Foods*, 89, 104958. https://doi.org/10.1016/j.jff.2022.104958

Koenig, W. A., Hochmuth D. H. & Joulain, D. (1998). Mass Finder 2.1 (Including the library) of terpenoids and related constituents of essential oils, E-B Verlag: Hamburg.

Machado, C. A., Oliveira, F. O., de Andrade, M. A., Hodel, K. V. S., Lepikson, H., & Machado, B. A. S. (2022). Steam Distillation for Essential Oil Extraction: An Evaluation of Technological Advances Based on an Analysis of Patent Documents. *Sustainability*, 14(12), 7119. https://doi.org/10.3390/su14127119

Makhija, I. K., Aswatha Ram, H. N., Shreedhara, C. S., Vijay Kumar, S. & Devkar, R. (2011). *In vitro* antioxidant studies of *Sitopaladi Churna*, a polyherbal Ayurvedic formulation. *Free Radicals and Antioxidants,* 1(2), *37–41.* https://doi.org/10.5530/ax.2011.2.8

Njoku I. S., Ichide M. U., Rahman N., Khan A.M., Otunomo I., Asekun, O. T. & Familoni O.B. (2021). Variation in the sesquiternoid composition of the volatile oils of *Annona muricata* Linn. from South Western Nigeria, caused by different drying methods. *Journal of Chemical Society of Nigeria* 46(4). https://doi.org/10.46602/jcsn.v46i4.656

Odusina, B. O., Oyeyemi, T. B., Fatoki, R. A., Ajikobi, W. A., Akinsunmbo, T. H., Ajimosun, I. E. & Osinubi, A. D. (2023). Chemical Constituents and Antioxidant Activities of the Essential Oil from Stem of *Olax Manii Mountain Top*

University Journal of Applied Science and Technology (MUJAST) 3(2) 33-38 https://mujast.mtu.edu.ng/storage/issues/Year_2023_Vol_3/Number_2/1712569535_Odusina%20et%20al.%20%202023.pdf

Ojimelukwe, P. C. (2022). Telfairia occidentalis: A blood booster, an antioxidant and an antihyperglycaemic agent. *International Journal of Food Sciences and Nutrition* 7(3):1-19 https://www.foodsciencejournal.com/assets/archives/2022/vol7issue3/7-3-13-398.pdf

Osibote, E. A., Adesida, S. A., Nwafor, S., & Iluobe, H. (2021). Chemical Composition and Antimicrobial Activities of Essential Oil from the Leaves of Acalypha wilkesiana on Pathogenic Microorganisms. Egyptian Academic Journal of Biological Sciences, G. Microbiology, 13(1), 19-28. https://doi.org/10.21608/eajbsg.2021.172882

Osinubi, A. D., Asekun, O. T., & Familoni, O. B. (2023) N-Aryl Amino Acids as Potential Antibacterial Agents. Reactions. 4(2):286-294. https://doi.org/10.3390/reactions4020017

Osinubi, A. D., Aberuagba, M. O., Gbadamosi, M. R. & Banjoko O. O. (2024). Exploring the Biological Potential of the Methanolic Crude Extract of *Capsicum Frutescens* Root. *Journal of Science and Information Technology* (JOSIT), 18 (1), 129-136. https://journals.tasued.edu.ng/index.php/josit/article/view/92

Osinubi A. D., Njoku, I. S. & Roleola B. T. (2025). Comparative Analysis of Hydro-Distillation and Steam-Distillation Techniques on the Chemical Composition of Turmeric (*Curcuma longa Linn*) Rhizomes. *International Journal of Basic Science and Technology* 11 (2), 170 - 176 https://ijbst.fuotuoke.edu.ng//issue/Apr-Jun-2025/Comparative-Analysis-of-Hydro-Distillation-and-Steam-Distillation-Techniques-on-the-Chemical-Composition-of-Turmeric-(Curcuma-longa-Linn)-Rhizomes/

Platzer, M., Kiese, S., Tybussek, T., Herfellner, T., Schneider, F., Schweiggert-Weisz, U., & Eisner, P. (2022). Radical scavenging mechanisms of phenolic compounds: A quantitative structure-property relationship (QSPR) study. *Frontiers in Nutrition*, 9, 882458. https://doi.org/10.3389/fnut.2022.882458

Povh, N. P., Garcia, C. A., Marques, M. O. & Meireles, M. A. A. (2001). Extraction of essential oil and oleoresin from chamomile (Chamomila recutita [L.] Rauschert) by steam distillation and extraction with organic solvents: a process design approach. *Revista Brasileira de Plantas Medicinais*, 4, 1-8. https://doi.org/10.70151/19g3g918

Ruth, O. O., Idowu, A. R., Bamikole, A. O., & Olusanya, A. R. (2023). Free radical scavenging-related antioxidant properties and inhibitory activities of *Telfairia occidentalis* seed protein hydrolysates and peptide fractions against two key enzymes implicated in diabetes mellitus. *International Journal of Peptide Research and Therapeutics*, *29*(5), 82. https://doi.org/10.1007/s10989-023-10555-w?urlappend=%3Futm_source%3Dresearchgate.net%26utm_medium%3Darticle

Sarkic, A. & Stappen, I. (2018). Essential oils and their single compounds in cosmetics—A critical review. Cosmetics, 5(1), 11. https://doi.org/10.3390/cosmetics5010011

Schwartz, B., Klamer, K., Zimmerman, J., Kale-Pradhan, P. B., & Bhargava, A. (2024). Multidrug Resistant *Pseudomonas aeruginosa* in Clinical Settings: A Review of Resistance Mechanisms and Treatment Strategies. *Pathogens (Basel, Switzerland)*, 13(11), 975. https://doi.org/10.3390/pathogens13110975

Sun, S., Yu, Y., Jo, Y., Han, J. H., Xue, Y., Cho, M., Bae, S. J., Ryu, D., Park, W., Ha, K. T., & Zhuang, S. (2025). Impact of extraction techniques on phytochemical composition and bioactivity of natural product mixtures. *Frontiers in Pharmacology*, 16, 1615338. https://doi.org/10.3389/fphar.2025.1615338

Teugwa C. M., Boudjeko T., Tugnoua T. B., Mejiato P. C. & Zofou D. (2013). Anti hyperglycaemic globulins from selected Cucurbitaceae seeds used as antidiabetic medicinal plants in Africa. BMC *Complementary and Alternative Medicine* 2013, 13:63. https://doi.org/10.1186/1472-6882-13-63

van Beek, T. A., & Joulain, D. (2018). The essential oil of patchouli, Pogostemon cablin: A review. *Flavour and Fragrance Journal*, *33*(1), 6-51. https://doi.org/10.1002/ffj.3418

World Health Organization. (2022). *Global antimicrobial resistance and use surveillance system (GLASS) report 2022*. World Health Organization. https://www.who.int/publications/i/item/9789240062702

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