https://chemclassjournal.com/
ChemClass Journal Vol. 9 Issue 4 (2025); 231 - 242
e-ISSN:3092-8214 p-ISSN:3092-8206
doi.org/10.33003/chemclass-2025-0904/16

Phytochemical Screening, Antioxidant Activity and Antimicrobial Activity of Leaves Extracts of Nigerian grown *Zingiber officinale*

***Azeez, G. O., Imran, M. O., Lawal, I. A., Ahmed, W. A and Lukmon, H.O.**

Science Laboratory Technology Department. The Oke-Ogun Polytechnic, Saki, Oyo State, Nigeria.

***Corresponding author:** Email: +2348051205557; azeezgafarolatunji@yahoo.com
Imran M.O.: +2348136683225; elimran2003@yahoo.com
Lawal I.A.: +2348050574989; lassmark2002@gmail.com
Ahmed W.A.: +2349057943650; ahmedayinde80@gmail.com
Lukmon H.O.: +2347039981893; hopeyemi709@gmail.com.

Abstract

Zingiber officinale rhizome is common and widely used as spice and herbal medicine in Nigerian houses but there is no record of its leaves uses. This study compared the phytochemicals, antioxidant and antimicrobial activities of methanol and ethyl acetate extracts of the leaves. Phytochemical screening, total flavonoids and total phenolic compounds of the extracts were determined using AOAC standard. The antioxidant activities of the extracts were established using the Ferric Reducing Antioxidant Power (FRAP) assay while the antimicrobial activities of the extracts were evaluated using broth microdilution method. The phytochemicals common to the two extracts were alkaloids, flavonoids and terpenoids, while only ethyl acetate extract possessed steroids. Quantitative analysis showed that the methanol extract had significantly higher total phenolic compounds (28.428 ± 0.005 mg GAE/g) and flavonoids (0.826 ± 0.003 mg CE/g) contents than the ethyl acetate extract. Antioxidant assays indicated superior ferric reducing antioxidant power (FRAP) for the methanol extract (156.140 ± 4.359 mg AAE/g) to ethyl acetate (106.048 ± 0.008 mg AAE/g). Antimicrobial evaluation demonstrated that ethyl acetate extract had lower minimum inhibitory concentration and minimum bactericidal concentration values against most tested bacterial and fungal strains, notably *Staphylococcus aureus, Bacillus subtilis, Escherichia coli*, and *Candida albicans*. These findings highlight that methanol is more effective in extracting polar phytoconstituents with strong antioxidant activity, while ethyl acetate yields non-polar compounds with higher antimicrobial efficacy. The results provide a basis for optimizing extraction methods for targeted pharmacological applications of ginger leaves in natural health products and antimicrobial therapies.

Keywords: Alkaloids, Antioxidant, Flavonoids, Phytoconstituents, *Zingiber officinale*.

Introduction

Zingiber officinale, commonly known as ginger, is a widely cultivated and economically significant spice with a long history of culinary, medicinal, and industrial applications. Known for its pungent flavor and aromatic qualities, its medicinal properties have been recognized for centuries. The rhizomes of the plant contain

© CSN Zaria Chapter

numerous bioactive compounds, including gingerols, shogaols, flavonoids, and terpenoids, which contribute to its broad-spectrum therapeutic effects as demonstrated by Olaleye et al [22]. In Southwestern Nigeria, ginger is both a vital spice and an important component of traditional medicine, used in treating ailments such as nausea, digestive disorders, inflammation, and infections as reported by Olayinka et al. [24].

The therapeutic benefits of ginger are largely attributed to its rich phytochemical contents, comprising phenolic compounds, terpenoids, alkaloids, and other bioactive molecules. These compounds are known for their antioxidant, antimicrobial, anti-inflammatory, and anticancer activities, making ginger a subject of growing interest in both traditional and modern healthcare systems [29]. Extraction of these bioactive compounds commonly employs methanol and ethyl acetate, two solvents valued for their ability to recover a broad spectrum of constituents (Sahira *et al*., 2020). Sulaimon et al. [34] reported that methanol is particularly effective in extracting polar compounds such as phenolics, flavonoids and alkaloids, whereas ethyl acetate more efficiently extracts non-polar and semi-polar constituents like terpenoids and steriods. Ginger cultivation benefits from fertile soils and favorable climate, producing high-quality plants with potent medicinal properties [24].

The antioxidant activity of the rhizome of ginger, mainly attributed to phenolic compounds, is well-documented. These compounds, particularly gingerols, neutralize free radicals, reduce oxidative stress, and enhance endogenous antioxidant defenses, lowering the risk of chronic diseases such as cancer, cardiovascular disorders, and neurodegeneration as demonstrated [30] Ginger's rhizome also exhibits antimicrobial activity against Gram-positive and Gram-negative bacteria, fungi, and viruses [23] This property has been explored for combating antimicrobial resistance, with methanol extracts shown to inhibit pathogens such as *Escherichia coli, Staphylococcus aureus,* and *Salmonella typhi* [21], while ethyl acetate extracts display notable antifungal activity against *Candida albicans* and *Aspergillus niger* [19]

The increasing demand for functional foods and herbal supplements underscores the need for evidence-based identification of plant extracts with potent, safe, and targeted biological activities. One of the well-known medicinal herbs usually adopted for various medicinal purposes is ginger, much research has been focused on its rhizome, but little attention has been paid to the leaves of the plant, which may contain bioactive compounds of high medicinal and pesticidal values. On this basis, this study was carried out to compare the phytochemical profiles, antioxidant capacities, and antimicrobial activities of methanol and ethyl acetate extracts of the dried leaves of *Zingiber officinale* grown in Saki, Oyo State, Nigeria.

2.0 Materials and Methods

2.1 Collection and preparation of samples

The whole plant was collected from a farm in Oje-Owode, located at latitude 8.623444° N and longitude 3.402950° E, Saki East Local Government, Oyo State, Nigeria and was identified in the Department of Biology , The Oke-Ogun Polytechnic, Saki. The leaves of the plant were air-dried at room temperature for seven days. The dried leaves were ground into powder using blender and kept in black nylon paper at room temperature until extraction.

2.2 Preparation of extracts

Powdered dried leaves of *Z. officinale* (100 g) was soaked in one litre of ethyl acetate for three days. This was then filtered using vacuum suction pump and the filtrate was then concentrated using rotary evaporator at 46 ^{O}C. The residue was successively treated with one litre of meyhanol, covered and allowed to stand for three days before filtration and concentration using vacuum suction pump and rotary evaporator at 46 ^{O}C.

2.3 Phytochemical screening

2.3.1 Test for alkaloids

One mL of Dragendoff's reagent was added to 2 mL of each extract. Orange red precipitate was observed which indicates the presence of alkaloids.

2.3.2 Test for flavonoids

Two millilitres (2 mL) of each extract were measured and shaken with three (3) drops of 10% NaOH. Initially, a deep yellow was observed but gradually turned colourless after the addition of two (2) drops of dilute hydrochloric acid.

2.3.3 Test for steroids

Two millilitres of the plant extract (2 mL) were shaken with 3 mL of chloroform. Concentrated H_2SO_4 (1 mL) was then added to the mixture along the wall of the test tube, a red colour appeared, indicating the presence of steroids.

2.3.4 Test for tannins

A measured volume (1 mL) of the extract was boiled with 4 mL of distilled water in a test tube. This was filtered and 0.1% $FeCl_3$ was then dropwisely added to it. The existence of tannins in the plant extracts was indicated by blue-black colour.

2.3.5 Test for terpenoids

Salkowski test was used; 5 mL of each extract was mixed with 2 mL of chloroform, and 3 mL concentrated H_2SO_4 was carefully added to form a layer. A reddish brown colouration formed at the interface, indicating the presence of terpenoids

2.4 Quantitative analysis

2.4.1 Determination of total phenolic content

Total phenolic concentration in the leaf extract was determined by using UV/Visible spectrophotometer followed the Folin–Ciocalteu assay, where gallic acid was used as a standard [14] The 0.5 mL of plant leaf extract was mixed with 3 mL of distilled water and 0.25 mL of

Folin-Ciocalteu reagent and shaken. This was kept in dark place for 5 minutes, 1 mL of 7.5% Na_2CO_3 was then added to it and incubated in dark place at room temperature for 90 minutes. Reagent blank was also prepared using distilled water. The absorbance of each of the blank and sample extracts was measured at 760 nm using a single beam UV/Visible spectrophotometer. The total phenolic compounds concentration in the extract was expressed as milligram of gallic acid equivalent (GAE) per 100 g sample (mg GAE/100 g). All the sample extracts were analyzed in triplicate.

2.4.2 Determination of total flavonoid content

Flavonoid content was determined using aluminium chloride assay according to established procedure [31]. Two millilitres of distilled water was added to 0.5 mL of the extract in 10 mL test tube. 0.15 mL of 5% $NaNO_2$ was then added to it and incubated for 5 minutes after which 0.15 mL 10% $AlCl_3$ was added. After 1 minute, 1 mL of 1 M NaOH was added and the volume was adjusted to 5 mL with distilled water. The absorbance of the solution was measured at 510 nm after 10 minutes. Catechin was used to prepare standard and total flavonoids contents of samples were expressed as mg catechin equivalent per 100 g of sample (mg CE/100 g sample). All the samples were analyzed in triplicate.

2.5 Antioxidant assay

2.5.1 Ferric reducing antioxidant power (FRAP)

FRAP solution (3.6 mL) was added to 400 µL of distilled water and incubated at 37˚C for 5 minutes. This solution was then mixed with 80 mL of each extract of the plant sample and incubated at 37˚C for 10 min. The absorbance of the mixture was measured at 593 nm using UV/Visible Spectrophotometer. The calibration curve was constructed from five standard solutions of $FeSO_4.7H_2O$ (0.1, 0.4, 0.8, 1.0, and 1.5 mM) using the same wavelength [6]

2.6 Determination of antimicrobial activity

2.6.1 Determination of Minimum Inhibitory Concentration (MIC)

The MIC was done using broth micro dilution method and 96 well plates. The extract samples were dissolved in double strength Tryptone Soya Broth (TSB) to obtain a solution of 2.5 mg/mL. A two-fold dilution series of the extracts was prepared in sterile 96 well plate to obtain concentration range of 1.25, 0.63, 0.31, 0.16, 0.078, 0.040, and 0.020 mg/mL. The drug used as the reference was ciprofloxacin, the reference drug was also diluted to obtain 10.0, 5.00, 2.50, 1.25, 0.625 and 0.133 µg/mL for the assay. After checking for growth or turbidity in the test plates (MIC determination). 10 µl of 0.20 mg/mL of *p*-iodonitrotetrazolium violet (p-INT) solution was added to the wells. The plates were further incubated at 37^{o}C for 30 minutes, the change in

the colour from yellow to pinkish red was an indication of bacterial /microbial growth.

2.6.2 Determination of Minimum Bactericidal Concentration (MBC)

Each of the microplate wells was inoculated with 10 µl of the microorganism and incubated at 37°C for 24 hours respectively. The concentration which showed no color change (red coloration) after the addition of 0.2 mg/mL of p-INT dye were streaked on solidified nutrient agar plates and incubated at 37°C for 24 hours The lowest concentration which showed no growth on nutrient agar medium was taken as minimum bactericidal concentration (MBC)/ minimum fungicidal concentration (MFC).

3.0 Results and Discussion

Discussion

The phytochemical screening results of *Zingiber officinale* (ginger) leaves extracts are revealed in Table 1. Alkaloids were detected in both extracts this is in line with the report of studies conducted on the plant rhizome (Rahmani *et al*. (2021); Nair *et al*. (2018). Terpenoids and flavonoids were present in the two extracts the result aligned with the finding of Wahid *et al*. (2023) in the rhizome of red *Z. officinale*. Flavonoids are extensively reported in ginger, commonly in ethanolic and aqueous extracts. Ogbunugafor *et al*. (2022) emphasized their roles as free radical scavengers and antidiabetic bioactive. Tannins were not detected in the two extracts, this is a contrast to the report of some studies, such as Umeoka (2024) and Adelusi *et al*. (2020), which reported tannins in ginger, primarily in rhizomes. Steroids showed the normal trend in accordance with polarities of the solvents, being absent in the methanol extract but present in the ethyl acetate extract. Although steroids are less commonly reported in ginger, they are occasional detected as reported by Sofowora *et al*. (2018), and is linked to anti-inflammatory effects.

The differences in phytochemical profiles between ethyl acetate and methanol extracts emphasize the solvent-dependent solubility of compounds. Previous studies indicate that methanol extracts generally contain a broader spectrum of phytochemicals due to methanol's polarity. This study slightly aligns with that trend for the present of alkaloids, flavonoids, and terpenoids in the methanol extract. The absence of tannins here contrasts with findings from aqueous extracts, suggesting variation based on plant part and solvents used for extraction. Alkaloids are known as powerful poison and have great biological activities such as anti-inflammatory, antimalarial, and anticancer activities (Adamski *et al.*, 2020). The presence of flavonoids and terpenoids in the leaves extracts of the plant is an indication of its biological and pharmacological potentials. Flavonoids have broad spectrum as antioxidants, anticancers, antidiabetic, and anti-inflammation (Chen *et al.*, 2023). Also, terpenoids have pesticidal, antioxidant, antimicrobial and cytotoxicity (Gozari *et al*., 2021).

Table 1: Phytochemical screening of leaf extracts of *Zingiber officinale*

Reagents	Ethyl acetate Extract	Methanol Extract
Alkanoids	+	+
Terpenoids	+	+
Tannins	-	-
Flavonoids	+	+
Steroids	+	-

Quantitative analysis showed in Table 2 revealed significant differences in total phenolic content between extracts: ethyl acetate (2.344 ± 0.536 mg gallic acid/g) and methanol (28.428 ± 0.005 mg gallic acid/g). The higher phenolic content in the methanol extract is consistent with higher polarity of methanol than ethyl acetate, which favors extraction of polar phenolic compounds. These were lower than the phenolic contents detected in the rhizome and callus (60.34± 0.43 – 33.6 ± 0.07mg gallic acid/g) of the plant reported by Ali *et al*. (2018). This revealed that ginger leaves possess lower phenolic compounds than its rhizome and callus. Phenolics are important antioxidants, neutralizing free radicals and reducing oxidative stress. Prakash and Gupta (2019) found similar trends, emphasizing that ginger leaves, though less rich in phenolics than rhizomes, still have appreciable antioxidant potential. Adelusi *et al*. (2020) also observed comparable phenolic levels in methanol ginger rhizome extracts but lower levels in leaves, suggesting plant part-dependent phenolic distribution. Flavonoid content was slightly higher in the methanol extract (0.826 ± 0.003 mg catechin/g) compared to the ethyl acetate extract (0.597 ± 0.004 mg catechin/g). This was found in lower amount in rhizome extract (40.25 ± 0.21 mg catechin/g) reported by Ali *et al*. (2018). Flavonoids are bioactive compounds with anti-inflammatory, antioxidant, and cardioprotective effects.

Table 2: Quantitative analysis of total phenolics and flavonoids in total phenolics and flavonoids in leaf extracts of *Zingiber officinale*

Parameters	Ethyl Acetate extract	Methanol extract
Total Phenolic Compound (mg gallic acid /g)	2.344±0.536	28.428±0.005
Flavonoid (mg quercetin /g)	0.597±0.004	0.826±0.003

In Table 3, antioxidant activities of the methanol and ethyl acetate extracts were revealed. Across all concentrations, methanol extracts demonstrated slightly higher values than ethyl acetate extracts. This is supported by the presence of higher amounts of phenolic compounds and flavonoids which are major contributors to antioxidant activity in methanol extracts than ethyl acetate. Both extract antioxidant activities were dose-dependent, indicating reduced efficacy at lower concentrations. The FRAP values in Table 4, further confirmed the superiority of the methanol extract (156.140 ± 4.359 mg AAE/g) over the ethyl acetate extract (106.048 ± 0.008 mg AAE/g). These values align with Ahmed *et al*. (2018), who reported similar FRAP ranges for ginger leaves, and with reports from less polar solvents for ethyl acetate. The calculated IC_{50} values were 2.35 for methanol and 2.58 for ethyl acetate. Both extracts exhibited strong activity at low concentrations. Methanol's slightly lower IC_{50} suggests marginally better efficacy. Overall, methanol remains the more effective solvent for extracting antioxidant compounds from *Z. officinale* leaves.

Table 3: Mean comparative study of Ethyl acetate & Methanol Extracts of *Zingiber officinale*

Conc. (µg/g)	Ethyl acetate extract	Methanol extract
400.00	35.44	36.23
200.00	32.16	32.84
100.00	25.70	28.82
50.00	21.99	23.75
25.00	18.89	21.65

Table 4: Antioxidant assay (FRAP) of leaf extracts of *Zingiber officinale*

Parameters	Ethyl acetate Extract	Methanol Extract
FRAP Conc. mg AAE/g	106.048±0.008	156.140±4.359

The antimicrobial activities of the extracts were revealed in Tables 5 and 6, both extracts showed strong growth inhibition activity (MIC: 0.78125 mg/mL) against *Staphylococcus aureus*, but the ethyl acetate extract had a lower MBC (0.78125 mg/mL) than the methanol extract (12.5 mg/mL). Gupta *et al*. (2020) reported similar MIC values but a lower MBC for ethyl acetate, aligning with these findings. The ethyl acetate extract exhibited lower MIC (0.78125 mg/mL) than the methanol extract (3.125 mg/mL) against *Bacillus subtilis* where their MBC was (3.125 mg/ml) and (12.5 mg/ml) for ethyl acetate and methanol, respectively. Sharma *et al*. (2021) reported higher MICs for each of the extracts (2.0 mg/ml) for ethyl acetate and (5.0 mg/mL) for methanol, the trend of greater effectiveness of ethyl acetate remains consistent. Ethyl acetate showed MIC and MBC values of 0.78125 mg/mL and 1.5625 mg/mL, respectively, compared to 6.25 mg/mL and 12.5 mg/mL for methanol against *Escherichia coli*, indicating higher potency of the ethyl acetate extract than methanol extract on the growth and death of the microorganism. The superiority of the ethyl acetate extract over methanol extract was also supported by Adebolu and Oladimeji (2020). The ethyl acetate showed equal MIC and MBC value (3.125 mg/mL), whereas methanol recorded MIC >50 mg/mL and MBC 12.5 mg/mL. It is inferred that ethyl acetate extract is a good antibacterial. Similar trend was revealed by Karuppiah and Rajaram (2019) on MIC values for ethyl acetate but better methanol activity than observed here.

Ethyl acetate extract with MIC and MFC values of 3.125 mg/mL and 6.25 mg/mL, respectively was more potent than methanol extract, with MIC and MFC values of 6.25 mg/mL and 25 mg/mL, respectively, against *Trichophyton rubrum*. Kadir *et al*. (2019) reported similar results, with slight variations in potency. Ethyl acetate extract showed MIC and MFC values of 3.125 mg/mL, whereas those of methanol was 12.5 mg/mL against *Candida albicans,* this suggests that the extracts are good antifungal against the fungus but ethyl acetate extract was more effective. These results agree with Ficker *et al*. (2020), who found stronger antifungal activity in ethyl acetate extracts.

Table 5: Minimum Inhibition Concentration (MIC) of leaf extracts of *Zingiber officinale*

	Ethyl acetate extract	Methanol extract
Organisms	MIC (mg/mL)	MIC (mg/mL)
Staphylococcus aureus	0.78125	0.78125
Bacillus substilis	0.78125	3.125
Escherichia coli	0.78125	6.25
Pseudomonas aeruginosa	3.125	>50
Trycophyton rubrum	3.125	6.25
Candida albicans	3.125	12.5

Note: Minimum Inhibition Concentration (MIC)

Table 6: Minimum Bactericidal Concentration (MBC) of leaf extracts of *Zingiber officinale*

	Ethyl acetate extract	Methanol extract
ORGANISMS	**MBC (mg/mL)**	**MBC (mg/mL)**
Staphylococcus aureus	0.78125	12.5
Bacillus substilis	3.125	12.5
Escherichia coli	1.5625	12.5
Pseudomonas aeruginosa	3.125	12.5
Trycophyton rubrum	6.25	25
Candida albicans	3.125	12.5

Note: Minimum bactericidal concentration (MBC).

Overall, ethyl acetate extract consistently demonstrated stronger antimicrobial activity than methanol extract, particularly against *S. aureus*, *B. subtilis*, and *E. coli*. This supports the hypothesis that less polar solvents extract more lipophilic antimicrobial compounds such as gingerols, shogaols, and certain flavonoids.

Conclusion

This work demonstrates that the choice of extraction solvent significantly influences the

phytochemical profile and bioactivity of *Z. officinale* leaves. ethyl acetate extracts showed stronger antimicrobial activity against both bacterial and fungal pathogens while methanol extracts is rich in total phenolics and flavonoids, exhibited superior antioxidant capacity. These findings suggest that methanol is better suited for developing antioxidant-rich formulations, whereas ethyl acetate is more effective for the prevention and treatment of microbial infection. The results highlight the importance of solvent selection in optimizing the pharmacological applications of ginger leaves and support their potential use in natural health products, functional foods, and alternative antimicrobial therapies. Further studies, including *in vivo* evaluations and compound isolation are recommended to fully harness the therapeutic value of ginger leaves.

References

1. Abdulkarim, S. M., Mustapha, A. & liyu, M. (2019). Comparative analysis of the antioxidant activity of ginger leaf extracts using different solvents. *Journal of Food Biochemistry*, 43(3),

2. Adamski, Z., Blythe, L.L., Milella, L. and Bufo, S.A (2020). Biological activities of alkaloids:

3. Adebolu, T. T. & Oladimeji, A. A. (2020). Antibacterial activity of *Zingiber officinale* (ginger) against *Escherichia coli* and other pathogens. *Journal of Medicinal Plants Research,* 14(4), 79-85.

4. Adelusi, T. I., Oboh, B. O. & Adetutu, A. (2020). Comparative evaluation of phytochemicals and antioxidant activities of rhizome and leaves of *Zingiber officinale*. *Journal of Medicinal Plants Research,* 14(4), 195–203.

5. Ahmed, M., Khan, A. A. & Siddiqui, Z. (2018). Antioxidant potential and phytochemical composition of *Zingiber officinale*: A comparative study of different solvent extracts. *Journal of Medicinal Plants Research,* 12(6), 102–110.

6. Al-Farsi M, Alasalvar C, Morris A, Baron M & Shahidi F (2005). Comparison of antioxidant activity, anthocyanins, carotenoids, and phenolics of three native fresh and sun-dried date (Phoenix dactylifera L.) varieties grown in Oman. *J. Agric. Food Chem*., 53, 7592

7. Ali, F., Khan, A. M. & Sharma, R. K (2021). Phytochemical and antimicrobial properties of *Zingiber officinale* rhizomes: A review. *Phytotherapy Research*, 35(4), 764-776.

8. Chen, S., Wang, X., Cheng, Y., Gao, H. & Chen, X (2023). A review of classification, biosynthesis, biological activities and potential applications of flavonoids, *Molecules*, *28*(13), 4982

9. Ficker, C., Kegley, S. E. & Kinser, M. L (2020). Antifungal activity of *Zingiber officinale* extracts against *Candida albicans*. *Phytotherapy Research,* 34(5), 1302-1308.

10. Gnanaraj, C., Ramaswamy, R. & Patel, S (2021). Antioxidant potential of *Zingiber officinale*: In vitro studies. *Food Chemistry*, 340, 127870.

11. Gozari, M., Alborz, M., El-Seedi, H. R. & Jassbi, A. R (2021). Chemistry, biosynthesis and biological activities of terpenoids and meroterpenoids in bacteria and fungi isolated

from different marine habitats, *European Journal of Medicinal Chemistry*, 210, 112975

12. Gupta, M., Singh, S. S. & Mehta, D (2020). Antibacterial potential of *Zingiber officinale* extracts against *Staphylococcus aureus*. *Pharmacognosy Journal,* 12(5), 1191-1196.

13. Gurumurthy, S., Muralidharan, M. & Pandian, S. K (2023). Synergistic effect of ginger and antibiotics against antibiotic-resistant bacteria. *Journal of Natural Medicines*, 45(2), 234-245

14. Kadir, A., Sulaiman, M. M. & Azmi, L (2019). Antifungal activity of *Zingiber officinale* (ginger) against *Trichophyton rubrum*. *Journal of Medicinal Plant Studies,* 7(4), 134-139.

15. Karuppiah, P. & Rajaram, P (2019). Antimicrobial efficacy of ginger (*Zingiber officinale*) extracts against *Pseudomonas aeruginosa*. *International Journal of Pharmaceutical Sciences and Research,* 10(3), 58-64

16. Khalil, R., Chukwuebuka, E. & Sharma, S (2020). The phytochemical composition and medicinal properties of *Zingiber officinale*. *Journal of Medicinal Chemistry*, 63(12), 842-856.

17. Lawag, I.V, Nolden, E.S, Schaper, A.A.M, Lim, L.Y & Cornelia, L (2023). A modified Folin-Ciocalteu Assay for the determination of total phenolics content in honey, *Appl. Sci*., 13(4), 2135

18. Nair, K. P., Shukla, V. & Thomas, A (2018). Phytochemistry and therapeutic applications of *Zingiber officinale*: A review. *Indian Journal of Natural Products and Resources,* 9(3), 211–223.

19. Nwinyi, O. C., Ude, A. L. & Akinmoladun, A. F (2022). Antimicrobial and antioxidant properties of ginger extracts: A comparative study. *International Journal of Food Science*, 56(7), 890-898.

20. Ogbunugafor, H. A., Eneh, F. U. & Onyekwelu, O. L (2022). Free radical scavenging and anti-diabetic potentials of flavonoids from ginger. *African Journal of Biochemistry Research,* 16(1), 20–30.

21. Okoh, A. I., Akinmoladun, F. F. & Okoh, O. O (2021). Antimicrobial activities of methanolic and ethyl acetate extracts of *Zingiber officinale* against foodborne pathogens. *International Journal of Food Science*, 56(6), 580-590.

22. Olaleye, M. T., Adebayo, E. A. & Lawal, M. O (2020). Medicinal properties of ginger and its therapeutic potentials in human health: A review. *Journal of Ethnopharmacology*, 267, 113726.

23. Olaniyi, T. O., Nwachukwu, J. U. & Akinmoladun, A. F (2021). Antimicrobial activities of *Zingiber officinale* extracts against pathogenic bacteria and fungi. *Pharmaceutical Biology*, 59(1), 532-539.

24. Olayinka, A. I., Adediran, O. S. & Bello, A. A (2021). The potential health benefits and industrial uses of *Zingiber officinale* from southwestern Nigeria. *Journal of Medicinal Plants Research*, 15(2), 45-58.

25. Prakash, A. & Gupta, C (2019). A comprehensive study on the phytochemical composition and bioactive properties of *Zingiber officinale*. *International Journal of Pharmaceutical Sciences and Research,* 10(8), 3600–3610.

26. Rahmani, A. H., Shabrmi, F. M. & Aly, S. M (2021). Active ingredients of ginger as potential candidates in the prevention and treatment of diseases via modulation of biological activities. *International Journal of Physiology, Pathophysiology and Pharmacology,* 13(1), 1–12.

27. Rukayah, M., Zawawi, N. Z. & Zaidi, I. S (2021). Flavonoid-rich ginger extracts and their biological activities: A review. *Food Research International*, 142, 110181.

28. Sahira, R. M., Adedayo, A. O. & Nwodo, O. F (2020). Comparative phytochemical analysis and medicinal properties of ginger extracts: A review. *Tropical Journal of Pharmaceutical Research*, 19(6), 1247-1256.

29. Sharma, D., Yadav, A. & Verma, D (2021). Antimicrobial activity of ginger (Zingiber officinale) extracts against *Bacillus subtilis*. *International Journal of Pharmacology,* 17(2), 98-102.

30. Sharma, G., Kumar, V. & Patra, J. K (2021). In vitro evaluation of antioxidant properties and bioactive components of ginger extracts. *Food Chemistry*, 337, 127820.

31. Shraim, A.M, Ahmed, T.A., Rahman, M.M., & Hijji, Y. M (2021). Determination of total flavonoid content by aluminum chloride assay: A critical evaluation, LWT-Food Science and Technology, 150(2021), 111932

32. Singh, R., Sharma, P. & Kumar, V (2020). Evaluation of antioxidant properties in *Zingiber officinale* using various solvent extractions. *Asian Journal of Pharmaceutical and Clinical Research*, 13(2), 45–49.

33. Sofowora, A., Ogunbodede, E. & Onayade, A (2018). The role and place of medicinal plants in the strategies for disease prevention. *African Journal of Traditional, Complementary and Alternative Medicines,* 15(1), 41–50.

34. Sulaimon, F. A., Adeyemo, S. M. & Akinmoladun, A. F (2022). Comparative extraction of bioactive compounds from *Zingiber officinale* using methanol and ethyl acetate. *Phytochemistry Reviews*, 21(3), 1027-1041.