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# PHYTOCHEMICAL INVESTIGATION BY GC-MS & IN VITRO ANTI-INFLAMMATORY ACTIVITY AND MOLECULAR DOCKING STUDY OF *MORINGA OLEIFERA*

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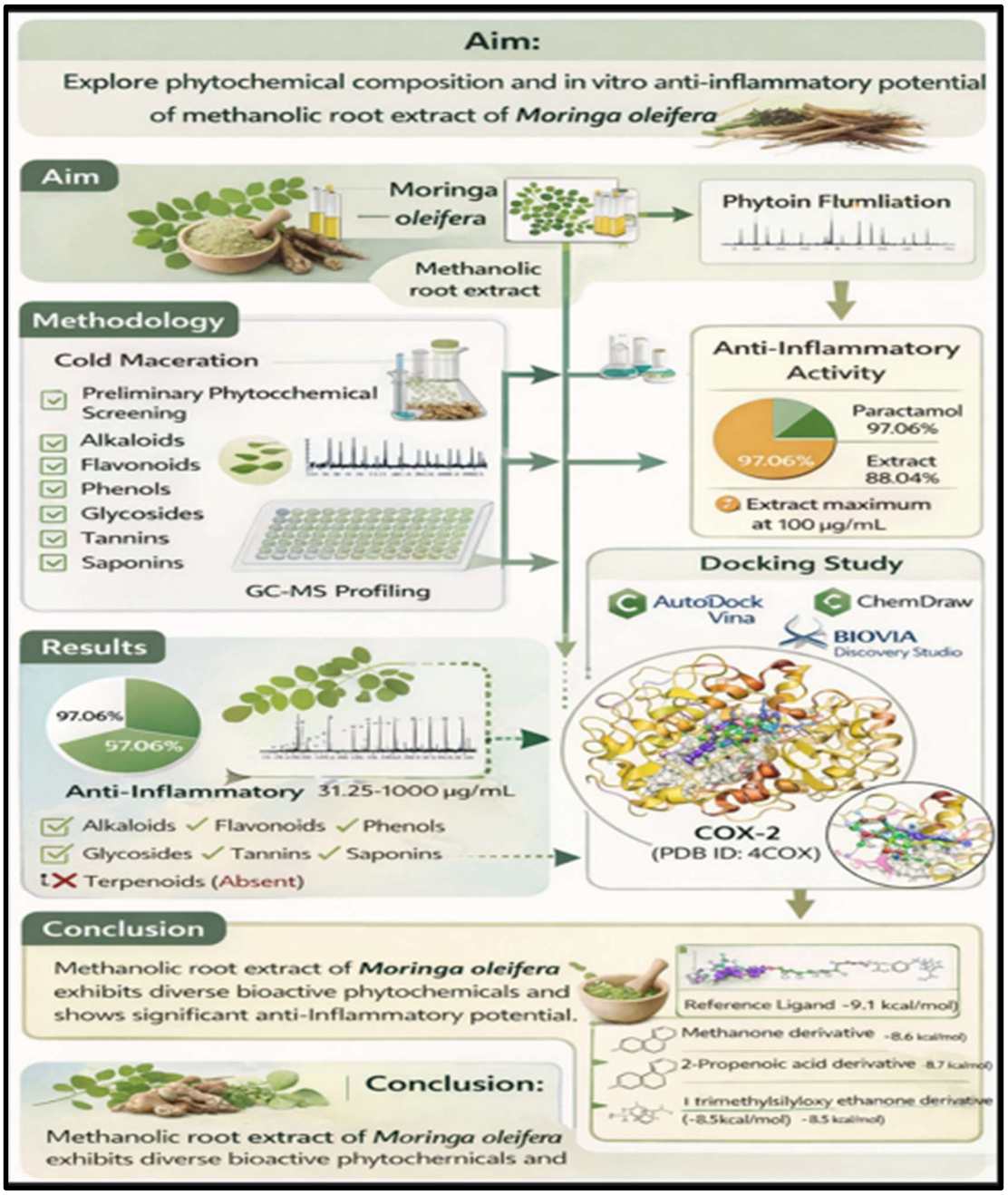
## ABSTRACT

**Aim:** The present study aimed to explore the phytochemical composition and in vitro anti-inflammatory potential of the methanolic root extract of *Moringa oleifera*, providing scientific validation for its traditional medicinal applications. **Methodology:** Roots of *Moringa oleifera* were collected, authenticated, and subjected to cold maceration using methanol. Preliminary phytochemical screening was conducted to detect bioactive constituents, including alkaloids, flavonoids, phenols, glycosides, tannins, saponins, and terpenoids. Major compounds were characterized through Gas Chromatography–Mass Spectrometry (GC-MS) analysis. The anti-inflammatory activity was evaluated in vitro employing the Albumin Denaturation Inhibition assay at concentrations ranging from 31.25 to 1000 µg/mL, with paracetamol as the reference standard. Percentage inhibition of protein denaturation was calculated. Molecular docking using AutoDock Vina and Biovia Discovery Studio revealed strong binding interactions between *Moringa oleifera* phytoconstituents and cyclooxygenase-II (COX-2; PDB ID: 4COX), a key enzyme involved in inflammation. **Results:** Phytochemical evaluation confirmed the presence of alkaloids, flavonoids, phenols, glycosides, tannins, and saponins, while terpenoids were absent. GC-MS profiling identified several bioactive constituents, including Methanone, (1-hydroxycyclohexyl) phenyl, 2-Propenoic acid, 1,7,7-trimethylbicyclo[2.2.1]hept-2-yl ester, 1,2-bis(trimethylsilyloxy-2-(3'-trimethylsilyloxyphenyl) ethanone. The extract exhibited dose-dependent anti-inflammatory activity, achieving a maximum inhibition of

88.04% at 1000 µg/mL. Paracetamol showed higher inhibition (97.06%), yet the extract demonstrated appreciable activity at elevated concentrations. Among the compounds, 2-Propenoic acid derivative (−8.7 kcal/mol), Methanone derivative (−8.6 kcal/mol), and a trimethylsilyloxy ethanone derivative (−8.5 kcal/mol) exhibited high binding affinity, comparable to the reference ligand (−9.1 kcal/mol). **Conclusion:** The methanolic root extract of *Moringa oleifera* possesses significant phytochemical diversity and in vitro anti-inflammatory activity.

**Keywords:** ***Moringa oleifera*, phytochemicals, GC-MS, anti-inflammatory, albumin denaturation**

**Graphical Abstract:**



## 1. INTRODUCTION

Herbal medicine is considered one of the most ancient and enduring healthcare systems, having evolved through generations of empirical knowledge and practices of indigenous healers **[1]**. It involves the utilization of plant-derived preparations for disease prevention and therapy, forming the cornerstone of several traditional medicinal systems worldwide. According to the World Health Organization (WHO), nearly 80% of the population in several Asian and African nations depends on herbal remedies for some aspects of primary healthcare **[2]**. Furthermore, a number of modern pharmaceuticals—including artemisinin, quinine, digitalis, and taxanes—originate from traditional herbal sources **[2]**. In recent decades, the growing concern over the toxicity and adverse reactions of synthetic drugs has encouraged the global population to turn toward herbal formulations, which are often regarded as safer, more economical, and environmentally sustainable alternatives **[1, 2]**. Medicinal plants are abundant in bioactive metabolites such as alkaloids, flavonoids, phenolics, and terpenoids that exhibit diverse pharmacological properties, including antioxidant, antimicrobial, and anti-inflammatory effects **[3]**. These naturally occurring phytochemicals contribute significantly to health maintenance and disease prevention by neutralizing free radicals and enhancing the body's detoxification mechanisms **[4]**. Numerous investigations have confirmed that phytochemicals like polyphenols, carotenoids, and saponins play a key role in reducing the risk of chronic disorders such as diabetes, cancer, and cardiovascular diseases **[5]**. Technological progress in analytical chemistry has enabled the precise identification and characterization of these bioactive constituents using advanced instrumental techniques, notably Gas Chromatography–Mass Spectrometry (GC-MS). This method provides high sensitivity and selectivity for separating and quantifying volatile and semi-volatile components in plant extracts **[6]**. GC-MS analysis has become indispensable for phytochemical profiling of medicinal plants, such as *Moringa oleifera*, whose methanolic and aqueous extracts have demonstrated potent antioxidant and anti-inflammatory activities **[7]**. The presence of such phytoconstituents offers valuable prospects for their application in pharmaceutical, nutraceutical, and cosmetic industries due to their efficacy in scavenging free radicals and protecting tissues from oxidative damage **[6, 7]**. Inflammation, a vital physiological defense mechanism, occurs in response to tissue injury, infection, or

chemical irritation and is marked by redness, swelling, pain, and elevated temperature **[9]**. While acute inflammation aids in healing, its chronic persistence can lead to the onset of several degenerative diseases, including arthritis, cardiovascular disorders, and malignancies. Non-steroidal anti-inflammatory drugs (NSAIDs) are widely prescribed to manage pain and inflammation; however, their prolonged use often results in severe side effects such as gastrointestinal bleeding, renal dysfunction, and cardiovascular risks **[10-33]**. Hence, the discovery of safer, plant-based anti-inflammatory compounds with minimal toxicity has become a major focus of current pharmacological research. The present investigation aims to perform phytochemical screening and GC-MS analysis of selected medicinal plant extracts to assess their anti-inflammatory potential, thereby providing scientific validation for their traditional therapeutic applications.

## 3.MATERIALS AND METHODS

### 3.1 COLLECTION, HERBARIUM AND AUTHENTICATION OF THE PLANT:

Following an extensive literature review, *Moringa oleifera* was chosen for the present investigation. Root samples collected in February 2025 from Haldia, West Bengal, were authenticated at the Central National Herbarium, Kolkata, and the preserved specimen was deposited in the Department of Pharmacognosy, Haldia Institute of Pharmacy.

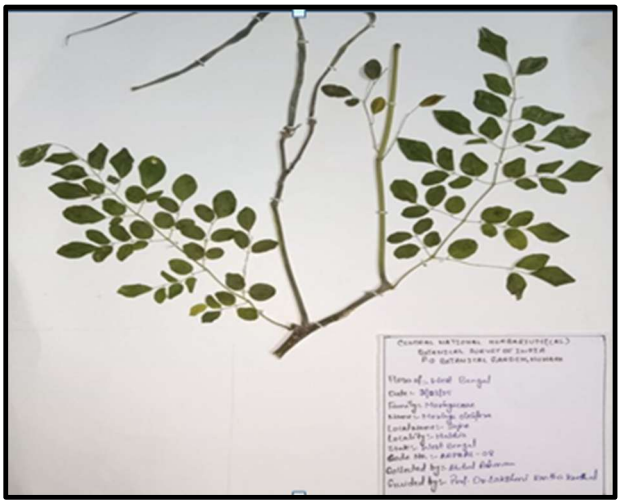


**Figure 1: Herbarium of *Moringa Oleifera* plant**

### 3.2 PREPARATION OF EXTRACT:

The selected plant material was extracted using the cold maceration technique. A total of 55 g of dried root powder was soaked in 440 ml of methanol, followed by filtration of the mixture, after which the obtained extract was

concentrated, dried, and stored for subsequent analysis **[34]**.

### 3.3 PRELIMINARY PHYTOCHEMICAL ANALYSIS:

The preliminary phytochemical tests of methanolic extract of *Moringa oleifera* is perform to detect for the presence of alkaloids, saponins, phytosterol, terpenoids, flavonoids, proteins, and amino acids, carbohydrates, glycosides, and tannins.

**Table 1: Preliminary Phytochemical Tests of Methanolic Extract**

| S. No. | Phytochemical Constituents | Name of the Test |
|---|---|---|
| 1 | Alkaloids | a) Wagner's Test b) Hager's Test |
| 2 | Glycosides | Killer–Killani Test |
| 3 | Tannins | Lead Acetate Test |
| 4 | Flavonoids | Alkaline Reagent Test |
| 5 | Phenols | Ferric Chloride Test |
| 6 | Terpenoids | Salkowski Test |
| 7 | Carbohydrates | a) Molisch's Test b) Fehling's Test |
| 8 | Saponins | Foam Test |

### 3.4 PHYTOCHEMICAL ANALYSIS BY GCMS:

A comprehensive GC–MS analysis was conducted to determine the phytochemical profile of *Moringa oleifera*. The extract was examined using a Thermo GC-Trace Ultra (Version 5.0) system linked to a Thermo MS DSQ II mass spectrometer, equipped with a TR 5-MS capillary column (30 m × 0.25 mm × 0.25 µm). Helium was employed as the carrier gas at a constant flow rate of 1.0 mL/min. The oven temperature was programmed from 40 °C to 250 °C at a rate of 5 °C/min. A 1 µL sample was injected, and the total run time was 45.84 minutes, with a scan range of m/z 50–650. The resulting chromatogram revealed major phytochemical constituents responsible for the anti-inflammatory potential of *Moringa oleifera* **[6]**.

### 3.5 IN VITRO ANTI-INFLAMMATORY ACTIVITY:

The anti-inflammatory activity of *Moringa oleifera* methanolic extract was assessed using the inhibition of albumin denaturation method. The reaction mixture (5 mL) comprised 0.2 mL of egg albumin, 2.8 mL of phosphate-buffered saline (PBS, pH 6.4), and 2 mL of extract at different concentrations, while double-distilled water served as the control. The mixture was incubated at 37 °C for 15 minutes, followed by heating at 70 °C for 5 minutes. After cooling, absorbance was recorded at 660 nm, with Paracetamol used as the reference standard. The percentage inhibition of protein denaturation was calculated using the formula: % Inhibition =

[(Vc − Vt)/Vc] × 100. Six concentrations ranging from 31.25 to 1000 µg/mL of both extract and standard were tested, and PBS was prepared according to established protocols **[28-35]**.

### 3.6 EVALUATION OF ANTI-INFLAMMATORY ACTIVITY BY MOLECULAR DOCKING STUDY:

Molecular docking was employed as a computational approach widely used in drug discovery to elucidate molecular interactions. This technique enabled the prediction of binding affinities and interaction patterns between small molecules (ligands) and target proteins (receptors). In the present investigation, two biologically relevant proteins cyclooxygenase-II (COX-2; PDB ID: 4COX), were selected due to their crucial roles in inflammation. The docking analysis was performed using AutoDock Vina, Chemdraw, Biovia discovery studio to evaluate the binding affinities of phytochemical constituents **(Table 3)** derived from *Moringa oleifera* with the selected protein targets **(Figure 2, 3)**.

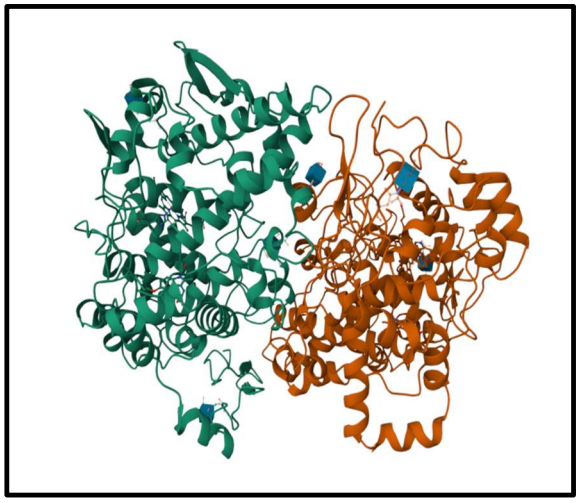


**Figure 2: (COX-2; PDB ID: 4COX)**

## RESULTS

### PHYTOCHEMICAL EVALUATION:

The preliminary phytochemical tests of methanolic extract (roots) of *Moringa Oleifera* indicates the presence of alkaloids, carbohydrates, flavonoids, phenols, glycosides, tannins and saponins and absence of terpenoids.

### 4.2 PHYTOCHEMICAL ANALYSIS OF *Moringa oleifera* USING GC-MS

The GC-MS analysis of these compounds was characterized using mass spectrometry coupled with gas chromatography. 10

compounds are selected depending upon the highest % area of the methanolic root extract of *Moringa oleifera* are summarized in **Figure 2, Table 3**.

**Table 2: Phytochemical Analysis of the Methanolic Root Extract of *Moringa oleifera***

| Phytochemical Constituents | Test Name | Result |
|---|---|---|
| Alkaloids | Wagner's Test | Present |
| | Hager's Test | Present |
| Carbohydrates | Fehling's Test | Present |
| | Molisch's Test | Present |
| Flavonoids | Alkaline Reagent Test | Present |
| Phenols | Ferric Chloride Test | Present |
| Terpenoids | Salkowski Test | present |
| Glycosides | Keller–Killiani Test | Present |
| Tannins | Lead Acetate Test | Present |
| Saponins | Foam Test | Present |

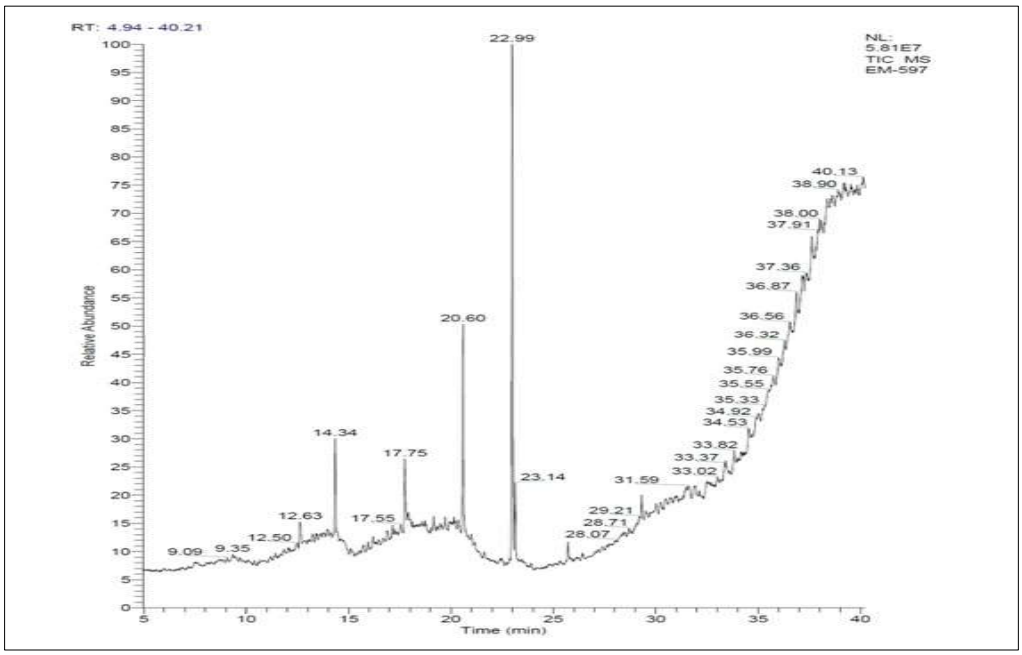
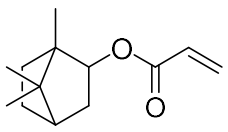



**Figure 3: Herbarium of *Moringa Oleifera* plant**

**Table 3: Gas chromatography–mass spectrometry (GC-MS) analysis of the methanolic extract of *Moringa oleifera* led to the identification of multiple bioactive compounds**

| Com. No | RT (min) | Compound Name | Area % | Molecular Formula | Nature of Compound |
|---|---|---|---|---|---|
| | 14.34 | 2-Propenoic acid, 1,7,7-trimethylbicyclo[2.2.1]hept-2-yl ester, | 2.57 | $C_{13}H_{20}O_2$ | Terpenoid (Monoterpene ester) |
| | 17.77 | Tricyclo[4.2.1.1(2,5)]dec-7-en-9-ol | 2.13 | $C_{10}H_{14}O$ | Terpenoid |
| | 20.60 | Methanone, (1-hydroxycyclohexyl)phenyl | 4.99 | $C_{13}H_{16}O_2$ | Aromatic ketone |
| | 22.99 | 4,7-Methano-1H-indene, 3a,4,5,6,7,7a-hexahydro-5-(2-propenyloxy) | 12.22 | $C_{13}H_{18}O$ | Terpenoid-like |
| | 25.72 | Hexadecanoic acid, methyl ester | 0.50 | $C_{17}H_{34}O_2$ | Fatty acid ester |
| | 29.31 | 6-Octadecenoic acid, methyl ester, (Z)- | 0.57 | $C_{19}H_{36}O_2$ | Unsaturated fatty acid ester |
| | 31.61 | Propanoic acid, 2-(3-acetoxy-4,4,14-trimethylandrost-8-en-17-yl) | 1.00 | $C_{27}H_{42}O_4$ | Steroid |
| | 31.92 | 1-Trichloroacetyl-3,5,7-triphenyl-1H-1,2-diazepine | 0.60 | $C_{25}H_{17}Cl_3N_2O$ | Alkaloid-like |
| | 33.41 | Tributyl(cyclohex-1-enyl)stannane | 0.94 | $C_{18}H_{36}Sn$ | Organometallic |

| | | | | | |
|---|---|---|---|---|---|
| | **33.82** | **Cholestano[7,8-a]cyclobutane, 3-methoxy-6-oxo-2'-methylene** | **0.60** | **$C_{10}H_9C_{l9}$** | **Steroid** |
| | **34.55** | **1,3-Bis-(trichloroacetyl)-2-(2,4-dimethoxyphenyl)-4-imidazoline** | **0.68** | **$C_{26}H_{43}NO_2Si$** | **Alkaloid-like** |
| | **34.94** | **Propanoic acid, 2-(3-acetoxy-4,4,14-trimethylandrost-8-en-17-yl)** | **0.82** | **$C_{27}H_{42}O_4$** | **Phenolic/sulfur compound** |
| | **36.00** | **6,8-bis(1',1'-Dimethylethyl)-4,9-bis(4'-methoxyphenyl)-3,5-dithiatricyclo** | **0.60** | **$C_{30}H_{36}O_2S_2$** | **Organosilicon** |
| | **36.56** | **3,3'-bis[2-Bromo-5-(trimethylsilyl)thiophene]** | **0.69** | **$C_{14}H_{20}Br_2S_2Si_2$** | **Fatty acid ester** |
| | **36.87** | **5-Heptenoic acid, methyl ester** | **0.94** | **$C_{24}H_{47}NO_5Si_2$** | **Organophosphorus** |
| | **37.17** | **2,8-Dichloro-3,7-dihydroxy-5-methoxy-4,6-diphenyldibenzophosphole 5-Oxide** | **1.41** | **$C_{25}H_{17}C_{l2}O_4P$** | **Organosilicon** |
| | **37.62** | **Cyclotrisiloxane, 1,3,5-trimethyl-1,3,5-triphenyl** | **1.09** | **$C_{21}H_{24}O_3Si_3$** | **Fatty acid ester** |
| | **37.97** | **1,2-bis(trimethylsilyloxy-2-(3'-trimethylsilyloxyphenyl)ethanone** | **1.19** | **$C_{17}H_{32}O_4Si_3$** | **Organosilicon** |
| | **38.37** | **4,6-dimethyl-2-oxo-5-trimethylsilylmethyl-6-heptenenitrile** | **1.15** | **$C_{21}H_{45}NO_3Si_4$** | **Alkaloid-like** |
| | **39.23** | **6-Amino-5-cyano-4-(5-cyano-2,4-dimethyl-1H-pyrrol-3-yl)-2-methyl-4H-pyran-3-carboxylic acid ethyl ester** | **0.56** | **$C_{17}H_{18}N_4O_3$** | **Terpenoid (Monoterpene ester)** |



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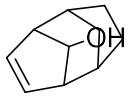

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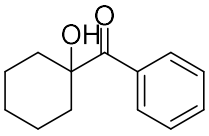

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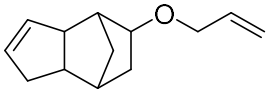

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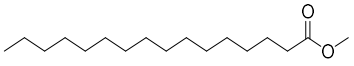

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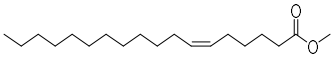

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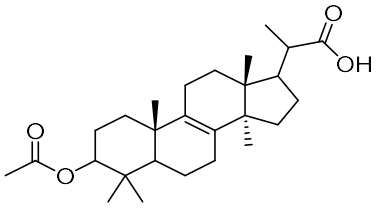

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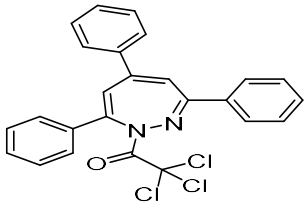

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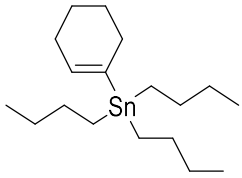

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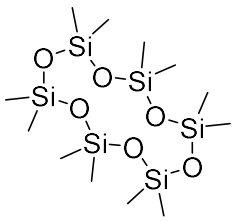

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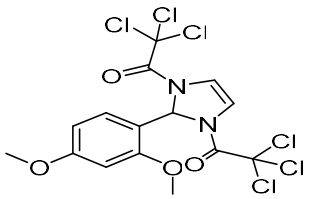

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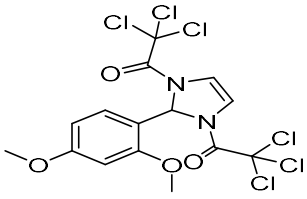

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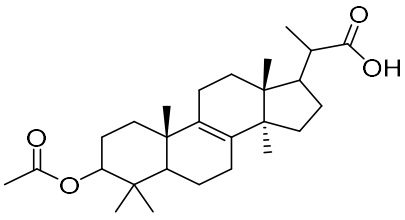

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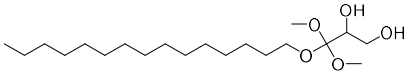

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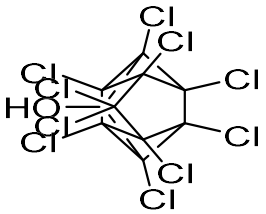


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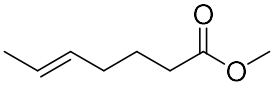


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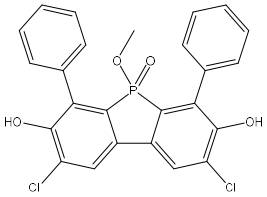


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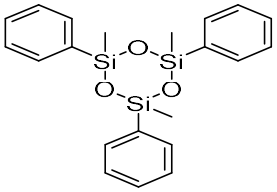


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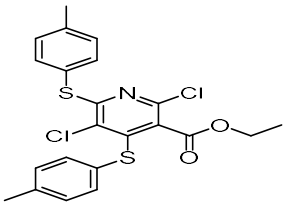


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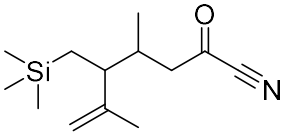


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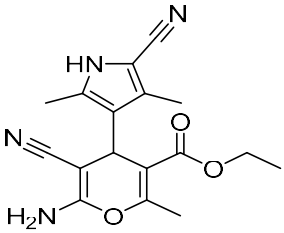


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## EVALUATION OF ANTI-INFLAMMATORY ACTIVITY:

The methanolic root extract of *Moringa oleifera* displayed concentration-dependent in-vitro anti-inflammatory activity in the Albumin Denaturation Inhibition assay. The extract achieved 88.04% inhibition at 1000 µg/ml, with reduced activity at lower doses. In comparison, paracetamol showed stronger and more consistent inhibition across all tested concentrations, reaching 97.06% at 1000 µg/ml. These findings suggest that the extract has notable anti-inflammatory effects at higher concentrations, although it is less potent than the standard drug **(Figure 4)**.

**Table 4: Effect of methanolic extract of *Moringa Oleifera* on albumin denaturation**

| Concentration (µg/ml) | Absorbance | % Inhibition |
|---|---|---|
| Control | 0.987 | – |
| 31.25 | 0.957 | 6.07 |
| 62.5 | 0.900 | 8.81 |
| 125 | 0.864 | 12.46 |
| 250 | 0.853 | 13.44 |
| 500 | 0.299 | 69.7 |
| 1000 | 0.118 | 88.04 |

**Table 5: Effect of paracetamol on albumin denaturation on albumin denaturation**

| Concentration (µg/ml) | Absorbance | % Inhibition |
|---|---|---|
| Control | 0.987 | – |
| 31.25 | 0.810 | 17.93 |
| 62.5 | 0.562 | 43.05 |
| 125 | 0.366 | 62.91 |
| 250 | 0.302 | 69.4 |
| 500 | 0.180 | 81.76 |
| 1000 | 0.029 | 97.06 |

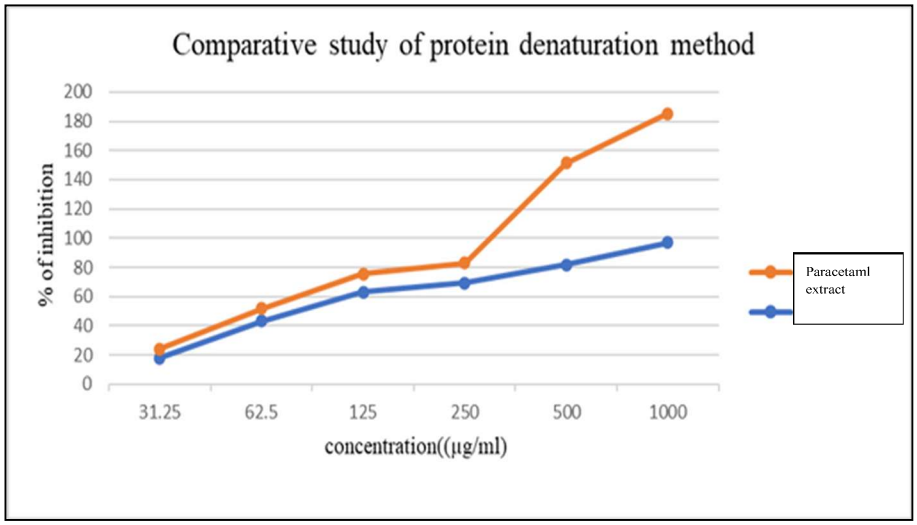


**Figure 4: Comparative study of albumin denaturation inhibition**

**EVALUATION OF ANTI-INFLAMMATORY ACTIVITY BY MOLECULAR DOCKING STUDY**

Based on the docking score or binding affinity with COX-II, Methanone, (1-hydroxycyclohexyl) phenyl, 2-Propenoic acid, 1,7,7-trimethylbicyclo[2.2.1] hept-2-yl ester,and 1,2-bis(trimethylsilyloxy-2-(3'-trimethylsilyloxyphenyl) ethanone show the highest binding affinity with these proteins. Based on docking score three compounds are selected.

**Table 6: Binding affinity of three best fitted identified compounds of *Moringa oleifera* with Cox-II**

| S. No. | Ligand | Docking Score |
|---|---|---|
| 1 | Pre attached ligand | -9.1 (kcal/mol) |
| 2 | Methanone, (1-hydroxycyclohexyl) phenyl | -8.6 (kcal/mol) |
| 3 | 2-Propenoic acid, 1,7,7-trimethylbicyclo[2.2.1]hept-2-yl ester | -8.7 (kcal/mol) |
| 4 | 1,2-bis(trimethylsilyloxy-2-(3'-trimethylsilyloxyphenyl) ethanone | -8.5 (kcal/mol) |

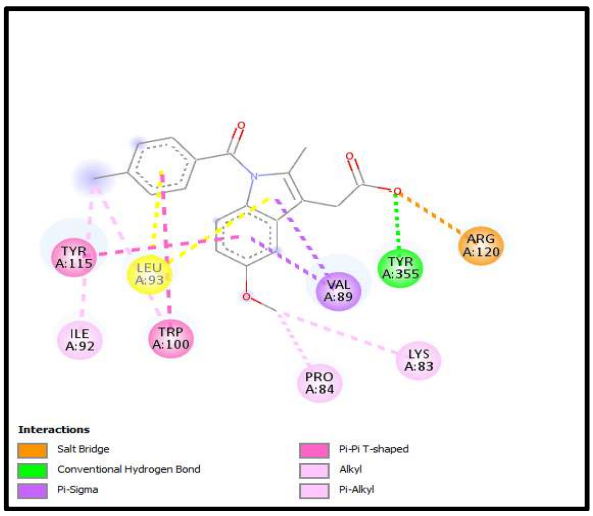


**Figure 4: Interaction of pre attached ligand No-3 With COX-II**

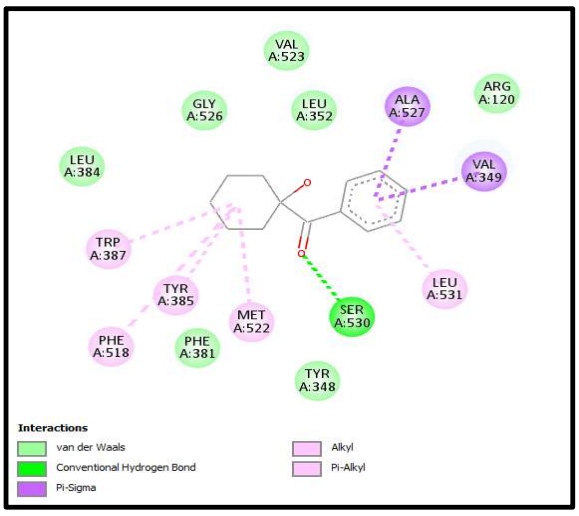


**Figure 5: Interaction of Compound With COX-II**

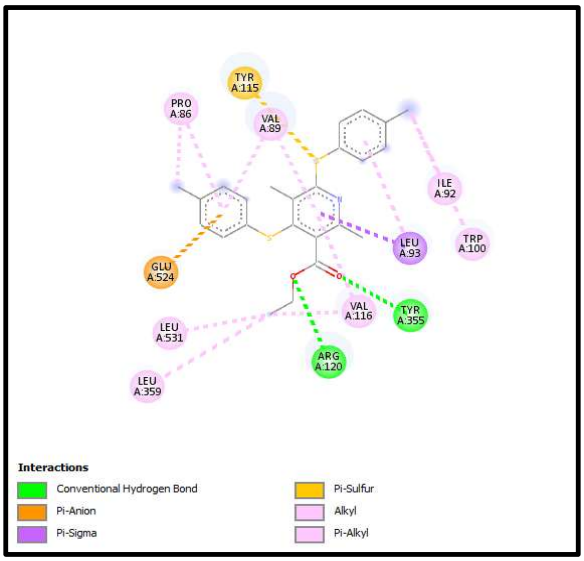


**Figure 6: Interaction of Compound No-1 No-18 With COX-II**

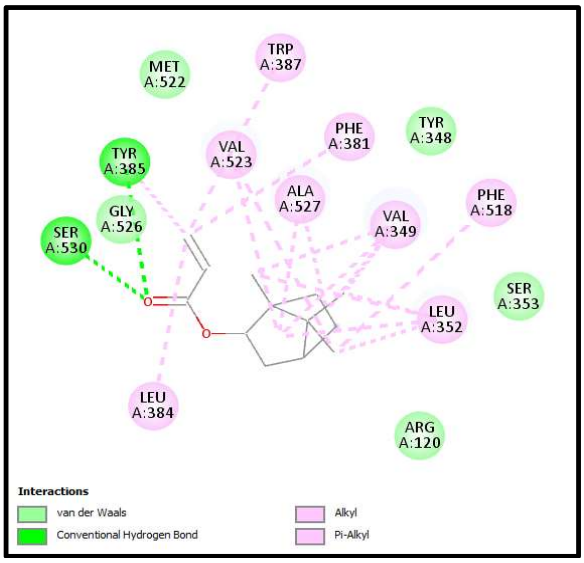


**Figure 7: Interaction of Compound With COX-II**

The molecular docking study indicated that the selected phytoconstituents of *Moringa oleifera* possessed significant binding affinity toward the COX-II enzyme, suggesting their possible inhibitory potential. The pre-docked (co-crystallized) ligand showed the highest affinity with a docking score of −9.1 kcal/mol and was used as the standard reference. Among the evaluated compounds, 2-Propenoic acid, 1,7,7-trimethylbicyclo[2.2.1]hept-2-yl ester exhibited the strongest interaction (−8.7 kcal/mol), followed by Methanone, (1-hydroxycyclohexyl) phenyl (−8.6 kcal/mol) and 1,2-bis(trimethylsilyloxy-2-(3'-trimethylsilyloxyphenyl) ethanone (−8.5 kcal/mol).Further analysis of the docking poses demonstrated that these ligands were effectively stabilized within the active site of COX-II through diverse intermolecular interactions. Conventional hydrogen bonding was observed with important amino acid residues such as SER A:530 and ARG A:120, contributing significantly to ligand stabilization. Additionally, hydrophobic interactions, including alkyl and π-alkyl contacts with residues such as VAL A:349, LEU A:352, LEU A:384, and ALA A:527, enhanced binding within the enzyme's hydrophobic cavity. Aromatic residues like PHE A:381, TYR A:385, and TRP A:387 participated in π-sigma and π-alkyl interactions, further strengthening ligand binding. Moreover, the larger ligand displayed additional interactions, including π-anion and π-sulfur bonds with residues such as GLU A:524 and TYR A:115, indicating a more intricate binding mechanism.

## DISCUSSION

The preliminary phytochemical screening of the methanolic root extract of *Moringa oleifera* indicated the presence of alkaloids, carbohydrates, flavonoids, phenols, glycosides, tannins, and saponins, while terpenoids were absent. These bioactive constituents are known to exhibit diverse pharmacological activities, including anti-inflammatory, antioxidant, and antimicrobial effects. GC-MS analysis further identified several compounds, such as Methanone, (1-hydroxycyclohexyl) phenyl, 2-Propenoic acid, 1,7,7-trimethylbicyclo[2.2.1]hept-2-yl ester, 1,2-bis(trimethylsilyloxy-2-(3'-trimethylsilyloxyphenyl) ethanone reflecting a complex chemical composition that may act synergistically to produce biological effects. The anti-inflammatory potential of the extract was evaluated in vitro using the Albumin Denaturation Inhibition assay. The extract showed a concentration-dependent inhibition, with the highest activity (88.04%) observed at 1000 µg/ml. Lower concentrations exhibited reduced activity, suggesting that higher doses are more effective in preventing protein denaturation. In comparison, paracetamol displayed a stronger and more consistent inhibitory effect across all tested concentrations, reaching 97.06% inhibition at 1000 µg/ml. These results suggest that the methanolic root extract of *Moringa oleifera* has notable anti-inflammatory activity, primarily at higher concentrations. The presence of flavonoids, phenols, and other bioactive constituents likely contributes to this effect. Although less potent than paracetamol, the extract represents a promising natural alternative for managing inflammation. Overall, the synergistic contribution of hydrogen bonding and hydrophobic interactions indicated the stable binding of these phytoconstituents within the active site of COX-II, highlighting their potential as effective anti-inflammatory agents.

## CONCLUSION

The methanolic root extract of *Moringa oleifera* displayed significant phytochemical diversity, comprising alkaloids, flavonoids, phenols, glycosides, tannins, and saponins, with terpenoids absent. GC-MS profiling revealed multiple bioactive compounds which may act synergistically to produce pharmacological effects. In vitro evaluation using the Albumin Denaturation Inhibition assay showed a clear dose-dependent anti-inflammatory response, achieving maximum inhibition (88.04%) at 1000 µg/ml, while lower concentrations were less effective. Although paracetamol exhibited stronger and more consistent inhibition across all concentrations, the extract demonstrated notable anti-inflammatory activity,

particularly at higher doses. These findings provide scientific support for the traditional medicinal use of *Moringa oleifera* and underscore its potential as a natural, plant-based therapeutic agent for the management of inflammatory disorders.

**Conflict of interest:** The authors have no conflicts of interest regarding this investigation.

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**REFERENCES:**

**[1]** Abdull Razis, A. F., Ibrahim, M. D., & Kntayya, S. B. (2014). Health benefits of *Moringa oleifera*. *Asian Pacific Journal of Cancer Prevention, 15*(20), 8571–8576. https://doi.org/10.7314/APJCP.2014.15.20.8571

**[2]** Abdulmalik, U., Halliru, Z., Umar, A., Musa, M., & Adam, A. S. (2024). Phytochemical screening, GCMS analysis and antibacterial activity of *Moringa oleifera* ethanolic and aqueous leaf extracts against some clinical isolates. *UMYU Journal of Microbiology Research, 9*(1), 34–45.

**[3]** Abubakar, A. R., & Haque, M. (2020). Preparation of medicinal plants: Basic extraction and fractionation procedures for experimental purposes. *Journal of Pharmacy and Bioallied Sciences, 12*(1), 1–10. https://doi.org/10.4103/jpbs.JPBS_175_19

**[4]** Adejumo, O. E., Kolapo, A. L., & Folarin, A. O. (2012). *Moringa oleifera* Lam. grown in Nigeria: In vitro antisickling activity on deoxygenated erythrocyte cells. *Journal of Pharmacy and Bioallied Sciences, 4*(2), 118–122. https://doi.org/10.4103/0975-7406.94812

**[5]** Aparna, V., Dileep, K. V., Mandal, P. K., Karthe, P., Sadasivan, C., & Haridas, M. (2012). Anti-inflammatory property of n-hexadecanoic acid: Structural evidence and kinetic assessment. *Chemical Biology & Drug Design, 80*(3), 434–439. https://doi.org/10.1111/j.1747-0285.2012.01418.x

**[6]** Azab, A., Nassar, A., & Azab, A. N. (2016). Anti-inflammatory activity of natural products. *Molecules, 21*(10), 1321. https://doi.org/10.3390/molecules21101321

**[7]** Bhalla, N., Ingle, N., Patri, S. V., & Haranath, D. (2021). Phytochemical analysis of *Moringa oleifera* leaves extracts by GC-MS and free radical scavenging potency for industrial applications. *Saudi Journal of Biological Sciences, 28*(12), 6915–6928. https://doi.org/10.1016/j.sjbs.2021.07.075

**[8]** Busse, W. (2000). The significance of quality for efficacy and safety of herbal medicinal products. *Drug Information Journal, 34*(1), 15–23. https://doi.org/10.1177/00928615000340 0102

**[9]** Chandra, S., Dey, P., & Bhattacharya, S. (2012). Preliminary in vitro assessment of anti-inflammatory property of *Mikania scandens* flower extract. *Journal of Advanced Pharmaceutical Education & Research, 2*(1), 25–31.

**[10]** Chandra, S., Chatterjee, P., Dey, P., & Bhattacharya, S. (2012). Evaluation of anti-inflammatory effect of ashwagandha: A preliminary study in vitro. *Pharmacognosy Journal, 4*(29), 47–49. https://doi.org/10.5530/pj.2012.29.7

**[11]** Damour, H., Oussekkour, M., Mennane, Z., & El Hajjaji, S. (2025). Phytochemical investigation by GC-MS and antimicrobial activities of *Boswellia carterii* extract. *Research Journal of Pharmacy and Technology, 18*(2), 571–578.

**[12]** De Cássia da Silveira e Sá, R., Andrade, L. N., & De Sousa, D. P. (2013). A review on anti-inflammatory activity of monoterpenes. *Molecules, 18*(1), 1227–1254. https://doi.org/10.3390/molecules180112 27

**[13]** Dhawan, B. N., Dubey, M. P., Mehrotra, B. N., & Tandon, J. S. (1980). Screening of Indian plants for biological activity: Part IX. *Indian Journal of Experimental Biology, 18*, 594–602.

**[14]** Durgawale, T. P., Khanwelkar, C. C., & Durgawale, P. P. (2018). Phytochemical screening using GC-MS and study of antioxidant activity. *Research Journal of Pharmacy and Technology, 11*(12), 5534–5540.

**[15]** Enerijiofi, K. E., Akapo, F. H., & Erhabor, J. O. (2021). GC–MS analysis and antibacterial activities of *Moringa oleifera*. *Bulletin of the National Research Centre, 45*(1), 179. https://doi.org/10.1186/s42269-021-00640-9

**[16]** Falcão, H. D., Lima, I. O., Santos, V. L., Dantas, H. D., Diniz, M. D., Barbosa-Filho, J. M., & Batista, L. M. (2005). Review of plants with anti-inflammatory activity studied in Brazil. *Revista Brasileira de Farmacognosia, 15*, 381–391.

**[17]** Ferreira, P. M., Farias, D. F., Oliveira, J. T., & Carvalho, A. D. (2008). *Moringa oleifera*: Bioactive compounds and nutritional potential. *Revista de Nutrição, 21*, 431–437.

**[18]** Gómez-Martínez, M., Ascacio-Valdés, J. A., Flores-Gallegos, A. C., et al. (2020). Phytochemical composition and antioxidant activity of *Moringa oleifera*. *Industrial Crops and Products, 151*, 112439. https://doi.org/10.1016/j.indcrop.2020.112439

**[19]** Guevara, A. P., Vargas, C., Sakurai, H., et al. (1999). An antitumor promoter from *Moringa oleifera*. *Mutation Research, 440*(2), 181–188.

**[20]** Han, L. Y., Yang, D., Wang, H. L., et al. (2025). Bone cement using isobornyl acrylate monomer. *New Journal of Chemistry, 49*(6), 2106–2115.

**[21]** Hu, Z., Yang, X., Ho, P. C., et al. (2005). Herb-drug interactions: A literature review. *Drugs, 65*(9), 1239–1282. https://doi.org/10.2165/00003495-200565090-00005

**[22]** Kanthal, L. K., Dey, A., Satyavathi, K., & Bhojaraju, P. J. (2014). GC-MS analysis of *Lactuca runcinata*. *Pharmacognosy Research, 6*(1), 58.

**[23]** Lako, J., Wattanapenpaiboon, N., Wahlqvist, M. L., & Trenerry, C. (2006). Phytochemical intakes of the Fijian population. *Asia Pacific Journal of Clinical Nutrition, 15*(2), 275.

**[24]** Leone, A., Spada, A., Battezzati, A., et al. (2015). Overview of *Moringa oleifera*. *International Journal of Molecular Sciences, 16*(6), 12791–12835.

**[25]** Mahmood, K. T., Mugal, T., & Haq, I. U. (2010). *Moringa oleifera*: A natural gift—A review. *Journal of Pharmaceutical Sciences and Research, 2*(11), 775.

**[26]** McEwen, C. N., & McKay, R. G. (2005). LC/MS: GC/MS ion source advantages. *Journal of the American Society for Mass Spectrometry, 16*(11), 1730–1738.

**[27]** Morton, J. F. (1991). The horseradish tree (*Moringa pterygosperma*). *Economic Botany, 45*(3), 318–333.

**[28]** Moyo, B., Masika, P. J., Hugo, A., & Muchenje, V. (2011). Nutritional characterization of *Moringa oleifera*. *African Journal of Biotechnology, 10*(60), 12925–12933.

**[29]** Paikra, B. K., & Gidwani, B. (2017). Phytochemistry and pharmacology of *Moringa oleifera*. *Journal of Pharmacopuncture, 20*(3), 194.

**[30]** Pandian, R. S., & Noora, A. T. (2019). GC-MS analysis of *Citrus medica*. *Research Journal of Pharmacy and Technology, 12*(4), 1823–1826.

**[31]** Parekh, J., & Chanda, S. (2007). Antimicrobial activity of medicinal plants. *Turkish Journal of Biology, 31*(1), 53–58.

**[32]** Rahayu, I., & Timotius, K. H. (2022). Phytochemical and antiviral activity of *Moringa oleifera*. *Molecules, 27*(13), 4017. https://doi.org/10.3390/molecules27134017

**[33]** Sahakitpichan, P., Mahidol, C., Disadee, W., et al. (2011). Glycosides from *Moringa oleifera*. *Phytochemistry, 72*(8), 791–795.

**[34]** Singh, B. N., Singh, B. R., Singh, R. L., et al. (2009). Antioxidant activity of *Moringa oleifera*. *Food and Chemical Toxicology, 47*(6), 1109–1116.

**[35]** Stohs, S. J., & Hartman, M. J. (2015). Safety and efficacy of *Moringa oleifera*. *Phytotherapy Research, 29*(6), 796–804.