

# Evaluation of *Momordica Charantia* L. And *Moringa Oleifera* L. Leaf Extracts as Natural Antibacterial Agents Against *Escherichia Coli* and *Staphylococcus Aureus*

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**Abstract** – The rapid emergence of antimicrobial resistance has become a major global health concern, necessitating the exploration of alternative sources of antibacterial agents. Medicinal plants have gained considerable attention due to their rich phytochemical composition and therapeutic potential. The present study aimed to compare the antibacterial activities of aqueous and ethanolic leaf extracts of *Momordica charantia* L. (Bitter melon) and *Moringa oleifera* L. (Moringa) against *Escherichia coli* and *Staphylococcus aureus* and to evaluate their efficacy in comparison with the standard antibiotic Norfloxacin. Sample of leaves of *Momordica charantia* L. (Bitter melon) and *Moringa oleifera* L. (Moringa) were collected from local Market of Brahmapur and Chatrapur, Odisha and tested in the Lab of Regional Institute of Biotechnology (RIB), Brahmapur Odisha, India. Fresh leaves of both plants were collected, dried, powdered, and extracted using aqueous and ethanolic solvents. Antibacterial activity was assessed by the disc diffusion method at different concentrations, while the minimum inhibitory concentration (MIC) was determined using spectrophotometric analysis. Gas Liquid Chromatography (GLC) was performed to identify the major bioactive constituents present in the extracts. The results demonstrated that ethanolic extracts exhibited greater antibacterial efficacy than aqueous extracts, indicating better extraction of active phytochemicals. Comparative analysis revealed that *Moringa oleifera* L. leaf extracts showed stronger inhibitory activity against both *E. coli* and *S. aureus* than *Momordica charantia* L. extracts, although Norfloxacin produced the highest zones of inhibition. GLC analysis identified quercetin as the major phytochemical in *Momordica charantia* L. and moringin as the predominant bioactive compound in *Moringa oleifera* L., which may contribute to their antimicrobial properties. Although the antibacterial activity of the plant extracts was lower than that of the standard antibiotic, the findings highlight the potential of these medicinal plants as natural sources of antimicrobial agents.

bacterial illnesses; however, their extensive application, particularly in resource-limited environments, generates selective pressure that fosters the development of resistance (Ahmed et al., 2024 & Salam et al., 2023). This results in heightened morbidity and death (Salam et al., 2023). Recent evidence reveals that AMR currently accounts for millions of fatalities annually, with forecasts indicating a substantial rise to 10 million deaths per year by 2050 (Murray et al., 2022). Studies have shown that medicinal plants contain a diverse assortment of bioactive chemicals, such as coumarins, flavonoids, phenolics, alkaloids, terpenoids, tannins, essential oils, lectins, polypeptides, and polyacetylenes (Peter et al., 2023). These natural products exhibit significant potential for addressing antibiotic resistance in bacterial pathogens. These naturally occurring phytochemicals have demonstrated diverse advantageous qualities, including antioxidant, antibacterial, and antifungal activity (Abass et al., 2024).

*Momordica charantia* L., commonly known as Bitter melon or bitter gourd, stands out due to its rich ethno-medicinal heritage and diverse phytochemical profile (Peter et al., 2023). The major chemical constituents of MC are classified as: (i) Heteropolysaccharides, mainly composed of galactose, glucose, arabinose, rhamnose, and mannose; (ii) Proteins and peptides, such as momordins, momorcharins, MAP30 and MC lectin, belonging to the ribosome-inactivating proteins family (RIPs) (Schrot et al., 2015) (iii) Terpenoids and saponins, such as cucurbitanes and cucurbitacines; (iv) Flavonoids and phenolic compounds; (v) Other compounds such as essential oils, fatty acids, amino acids, and sterols (Dandwate et al., 2016). This chemical profile aligns with several studies that have characterized *M. charantia* L. leaves as rich in polyphenolic and steroidal compounds, particularly flavonoids, which are well-established antimicrobial agents (Aumeeruddy et al., 2020). Flavonoids exert antibacterial effects by disrupting bacterial membranes, chelating metal ions essential for bacterial enzymes, and inhibiting nucleic acid synthesis (Donadio et al., 2021).

*Moringa oleifera* L., commonly known as drumstick tree or horseradish tree, belongs to the family Moringaceae and is widely cultivated in tropical and subtropical regions. The plant is highly valued for its nutritional and medicinal importance. Various parts of the plant, including leaves, seeds, roots, flowers, and bark, have been traditionally used in folk medicine for the treatment of several diseases such as inflammation, diabetes, hypertension, gastrointestinal disorders, and microbial infections (Anwar et al., 2007). Among these plant parts, the leaves are particularly rich in vitamins, minerals, proteins, flavonoids, alkaloids, tannins, saponins, and phenolic compounds that contribute to their therapeutic properties (Saini et al., 2016).

The antibacterial effect of the plant is mainly attributed to the presence of phytochemical such as quercetin, kaempferol,

**Key Words:** *Momordica charantia* L., *Moringa oleifera* L., antibacterial activity, *Escherichia coli*, *Staphylococcus aureus*, MIC, phytochemical

## 1. INTRODUCTION

AMR is a natural phenomenon in which microorganisms (bacteria, fungi, and protozoa) acquire the capability to endure and proliferate despite the administration of medications such as antibacterial, antifungal, and antiprotozoal antibiotics (Aggarwal et al., 2024). Antibiotics are essential for addressing

isothiocyanates, and other phenolic compounds that can disrupt bacterial cell walls, inhibit enzyme activity, and interfere with microbial metabolism (Fahey, 2005).

## 2. OBJECTIVE OF THE STUDY

To evaluate and compare the antibacterial activities of *Momordica charantia* L. and *Moringa oleifera* L. extracts against *Escherichia coli* and *Staphylococcus aureus*.

1. To comparatively evaluate the antibacterial activity of aqueous and ethanolic extracts of *Momordica charantia* L. and *Moringa oleifera* L. against *Escherichia coli* and *Staphylococcus aureus* using disc diffusion assay and MIC analysis.
2. To analyze the influence of extraction solvents on the antibacterial efficacy of Bitter melon and Moringa extracts and compare their inhibitory potential against Gram-positive and Gram-negative bacteria.
3. To identify and compare the major bioactive phytochemical constituents responsible for antibacterial activity through Gas Liquid Chromatography (GLC) analysis.
4. To identify and compare the major bioactive phytochemicals constituents responsible for antibacterial activity through Gas Liquid Chromatography (GLC) analysis.

## 3. REVIEW OF LITERATURE

Medicinal plants have been extensively investigated for their antimicrobial properties due to the increasing emergence of antibiotic-resistant microorganisms. Plant-derived bioactive compounds such as flavonoids, alkaloids, tannins, phenols, and saponins are known to possess antibacterial activity against various pathogenic bacteria (Cowan, 1999). These phytochemicals interfere with microbial metabolism, protein synthesis, and cell wall formation, thereby inhibiting bacterial growth.

*Momordica charantia* L., commonly known as Bitter melon, is an important medicinal plant traditionally used for the treatment of diabetes, inflammation, gastrointestinal disorders, and infections. Various studies have reported the antibacterial activity of *Momordica charantia* L. leaf extracts against both Gram-positive and Gram-negative bacteria. Leelaprakash et al. (2011) evaluated the antibacterial activity of Bitter melon leaf extracts and reported significant inhibitory effects against *Escherichia coli* and *Staphylococcus aureus*. The study suggested that ethanolic extracts exhibited greater antibacterial activity compared to aqueous extracts due to better extraction of phytochemicals.

Lucena Filho et al., (2015) investigated the antibacterial properties of *Momordica charantia* L. leaf extracts and observed that the ethanolic extract produced larger zones of inhibition against pathogenic bacteria than aqueous extracts. The authors attributed the antibacterial effect to the presence of flavonoids, tannins, alkaloids, and phenolic compounds present in the leaves. Similarly, Ríos and Recio (2005) reported that medicinal plants rich in phenolic compounds possess strong antimicrobial potential against several bacterial pathogens.

Several phytochemical investigations have identified quercetin and related phenolic compounds as important bioactive constituents in *Momordica charantia* L. These compounds exhibit antimicrobial activity by damaging bacterial cell membranes and interfering with cellular metabolic processes. The antibacterial efficacy of Bitter melon extracts has therefore been associated with the synergistic action of multiple phytochemicals.

*Moringa oleifera* L. is another medicinal plant widely recognized for its nutritional and therapeutic importance. Different parts of the plant including leaves, roots, seeds, and bark have been used in traditional medicine for the treatment of inflammation, microbial infections, and nutritional deficiencies (Anwar et al., 2007). The leaves are rich in vitamins, minerals, flavonoids, tannins, phenols, and isothiocyanates, which contribute to their medicinal value.

Saadabi & Abu Zaid (2011) evaluated the antibacterial activity of *Moringa oleifera* L. leaf extracts against human pathogenic bacteria and reported inhibitory activity against *Escherichia coli* and *Staphylococcus aureus*. The study demonstrated that ethanolic extracts exhibited greater antibacterial activity than aqueous extracts due to improved solubility of active phytochemicals in ethanol.

Fahey (2005) reviewed the medicinal properties of *Moringa oleifera* L. and stated that the plant possesses antimicrobial, antioxidant, anti-inflammatory, and nutritional properties. The antibacterial activity of *Moringa oleifera* L. has been linked to the presence of bioactive compounds such as quercetin, kaempferol, and other phenolic constituents that inhibit microbial growth.

Previous studies have also demonstrated that Gram-positive bacteria are generally more susceptible to plant extracts than Gram-negative bacteria because the outer membrane present in Gram-negative bacteria acts as an additional permeability barrier against antimicrobial compounds. However, several medicinal plants extract including *Momordica charantia* L. and *Moringa oleifera* L. have shown activity against both bacterial groups.

Although numerous studies have independently investigated the antibacterial activity of *Momordica charantia* L. and *Moringa oleifera* L., limited comparative studies have evaluated both medicinal plants simultaneously under similar experimental conditions using aqueous and ethanolic extracts against *Escherichia coli* and *Staphylococcus aureus*. Therefore, comparative evaluation of these medicinal plants may provide valuable insights into their effectiveness as natural antibacterial agents and their potential use in future pharmaceutical applications.

## 4. MATERIALS AND METHODS

### 4.1 Collection of Plant Materials

Fresh, disease free, and young leaves of *Momordica charantia* L. (Bitter melon) were collected from local agricultural field in a rural region of Chatrapur and leaves of *Moringa oleifera* L. (Moringa) were procured from local vegetable market of Brahmapur, Odisha. The plant materials were cleaned, shade dried, and grind into fine powder using a mechanical grinder.

### 4.2 Preparation of Plant Extracts

Aqueous and ethanolic extracts of Bitter melon and Moringa were prepared using solvent extraction method. About 10g of powdered plant material was mixed with 100 ml of distilled water and ethanol separately in a ratio of 1:10 (w/v). The mixtures were kept under continuous shaking for 72 hours at room temperature. The extracts were filtered using Whatman No.1 filter paper and concentrated using rotary evaporation. The concentrated extracts were stored at 4°C until further experimental analysis.

### 4.3 Test microorganisms

The bacterial strains used in the present study were *Escherichia coli* (MTCC-443) and *Staphylococcus aureus* (MTCC-1430). Pure cultures were obtained from the Regional Institute of Biotechnology (RIB), Brahmapur, and sub cultured onto solidified nutrient agar medium using a sterile inoculation loop and incubated at optimum temperature for growth. The cultures were sub cultured every 2–3 days to maintain sterility and active growth.

### 4.4 Preparation of Culture Media

Nutrient agar and nutrient broth media were prepared and sterilized by autoclaving at 121°C for 15 minutes. The sterilized media were cooled and poured aseptically into sterile Petri plates for antibacterial assay.

### 4.5 Preparation of Bacterial Inoculum

Fresh bacterial inoculum was prepared by inoculating bacterial colonies into sterile nutrient broth followed by incubation at 37°C for 18–24 hours. The turbidity of bacterial suspension was adjusted to match McFarland standard for uniform inoculation.

### 4.6 Preparation of Antibiotic Discs

Sterile paper discs were prepared from thick chromatography paper and sterilized using 70% ethanol followed by ultraviolet (UV) irradiation inside a laminar airflow chamber. Uniform circular discs were punched out aseptically using a sterile paper puncher. Crude extracts of Bitter melon and Moringa were prepared at a stock concentration of 100 mg/ml. Working concentrations of 10 mg/ml and 5 mg/ml were prepared separately for both aqueous and ethanolic extracts using sterile distilled water and ethanol respectively. The sterile paper discs were immersed in the prepared extract solutions for approximately 15 minutes to ensure proper impregnation. After soaking, the discs were removed aseptically using sterile forceps and dried inside the laminar airflow chamber before use in antibacterial assay.

### 4.7 Antibacterial activity by Disc Diffusion Method

The antibacterial activity of aqueous and ethanolic extracts of *Momordica charantia* L. and *Moringa oleifera* L. was evaluated using disc diffusion assay by pour plate technique. Sterile molten nutrient agar medium was inoculated with bacterial cultures and poured aseptically into sterile petri plates. After solidification of the medium, sterile filter paper discs impregnated with plant extracts were carefully placed on the agar surface using sterile forceps. Standard antibiotic discs were used as positive control, while solvent-treated discs served as negative control. The plates were incubated at 37°C for 24 hours, and antibacterial activity was determined by measuring the diameter of zones of inhibition.

### 4.8 Determination of Minimum Inhibitory Concentration (MIC)

The MIC of plant extracts was determined using standard serial broth dilution method. The first test tube contained 10 ml sterile nutrient broth, while subsequent tubes contained 9 ml broth. Stock extract (100 mg/ml) was diluted to prepare 10 mg/ml working solution. Serial two-fold dilutions were carried out to obtain concentrations of 10 mg/ml, 5 mg/ml, 2.5mg/ml, 1.25 mg/ml, 0.625 mg/ml, and 0.312 mg/ml. Each tube was inoculated with standardized bacterial suspension and incubated at 37°C for 24 hours. Following incubation, bacterial growth was assessed by measuring optical density (OD) at 600 nm using a spectrophotometer. The MIC was considered as the lowest concentration showing no visible growth or significant reduction in turbidity compared to the control.

### 4.9 Gas Liquid Chromatography (GLC) Analysis

Gas Liquid Chromatography (GLC) analysis was performed to identify the major phytochemical constituents present in Bitter melon and Moringa extracts. The chromatographic peaks obtained were analyzed to identify major bioactive compounds responsible for antibacterial activity, including quercetin in Bitter melon and moringin in Moringa.

## 5. RESULT AND DISCUSSION

### 5.1 Zone of Inhibition against *Escherichia coli*

The ethanolic extract of *Moringa oleifera* L. at 10 mg/mL concentration exhibited the highest antibacterial activity against *Escherichia coli* with a zone of inhibition of 0.5 cm, whereas the 5mg/mL concentration showed comparatively lower inhibitory activity. Aqueous extract of Moringa also demonstrated significant antibacterial activity against *E. coli* at both concentrations. In comparison, aqueous and ethanolic extracts of *Momordica charantia* L. exhibited lower zones of inhibition against *Escherichia coli* than Moringa extracts.

**Table 1:** Zone of Inhibition of aqueous extracts of Bitter melon and Moringa against *Escherichia coli*

| Concentration | Bitter melon Extract (Aqueous) | Moringa extract (Aqueous) |
|---------------|--------------------------------|---------------------------|
| 5mg           | 1mm                            | 2mm                       |
| 10mg          | 2mm                            | 3mm                       |
| Norfloxacin   | 5mm                            | 8mm                       |

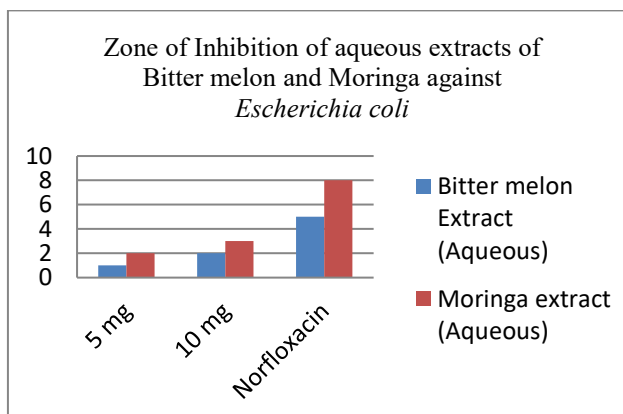


**Table 2:** Zone of Inhibition of ethanolic extracts of Bitter melon and Moringa against *Escherichia coli*

| Concentration | Bitter melon extract (Ethanol) | Moringa extract (Ethanol) |
|---------------|--------------------------------|---------------------------|
| 5mg           | 1mm                            | 4mm                       |
| 10mg          | 2mm                            | 5mm                       |
| Norfloxacin   | 6mm                            | 9mm                       |

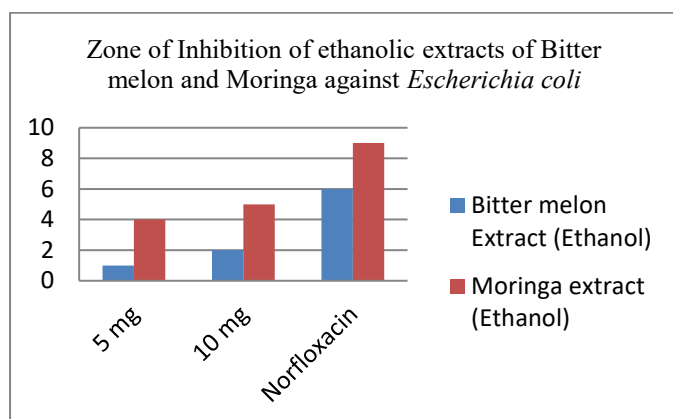


Fig- 1



Fig- 2



Fig- 3



Fig- 4

Fig.1: Zone of Inhibition of aqueous extract of Bitter melon against *Escherichia coli*

Fig.2: Zone of Inhibition of aqueous extract of Moringa against *Escherichia coli*

Fig.3: Zone of Inhibition of ethanolic extract of Bitter melon against *Escherichia coli*

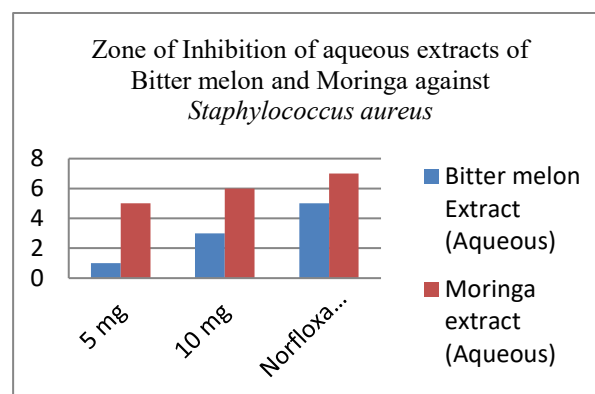
Fig.4: Zone of Inhibition of ethanolic extract of Moringa against *Escherichia coli*

## 5.2 Zone of Inhibition against *Staphylococcus aureus*

Against *Staphylococcus aureus*, the aqueous extract of Bitter melon produced inhibition zones of 0.1cm and 0.2cm at 5mg/ mL and 10mg/ mL concentrations respectively. Ethanolic Bitter melon extracts demonstrated inhibition zones of 0.2cm and 0.1cm at 5mg/ mL and 10mg/ mL concentrations respectively. The aqueous extract of Moringa exhibited inhibition zones of 0.5cm and 0.6cm at 5 mg/ mL and 10 mg/ mL concentrations respectively against *Staphylococcus aureus*. Similarly, the ethanolic extract of Moringa showed inhibition zones of 0.7 cm and 0.9 cm at 5mg/ mL and 10mg/ mL concentrations respectively. Norfloxacin exhibited the highest antibacterial activity against *Staphylococcus aureus* in Moringa extracts.

**Table 3:** Zone of Inhibition of aqueous extracts of Bitter melon and Moringa against *Staphylococcus aureus*

| Concentration | Bitter melon extract (Aqueous) | Moringa extract (Aqueous) |
|---------------|--------------------------------|---------------------------|
| 5mg           | 1 mm                           | 5 mm                      |
| 10mg          | 3 mm                           | 6 mm                      |
| Norfloxacin   | 5 mm                           | 7 mm                      |



| Concentration | Bitter melon Extract (Ethanolic) | Moringa extract (Ethanolic) |
|---------------|----------------------------------|-----------------------------|
| 5mg           | 1 mm                             | 7 mm                        |
| 10mg          | 2 mm                             | 9 mm                        |
| Norfloxacin   | 6 mm                             | 8 mm                        |

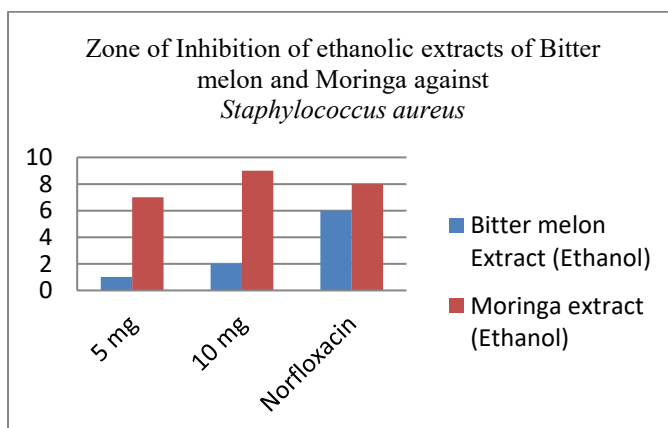


Fig- 5



Fig- 6



Fig- 7



Fig- 8

Fig 5: Zone of Inhibition of aqueous extract of Bitter melon against *Escherichia coli*

Fig 6: Zone of Inhibition of aqueous extract of Moringa against *Escherichia coli*

Fig 7: Zone of inhibition of ethanolic extract of Bitter melon against *Staphylococcus aureus*

Fig 8: Zone of Inhibition of ethanolic extract of Moringa against *Staphylococcus aureus*

Comparative evaluation demonstrated that *Moringa oleifera* L. exhibited stronger antibacterial activity than *Momordica charantia* L. against both *Escherichia coli* and *Staphylococcus aureus*. Ethanolic extracts of both medicinal plants showed comparatively greater antibacterial efficacy than aqueous extracts, indicating better extraction of bioactive phytochemical constituents in ethanol. The antibacterial activity of all extracts increased with increasing concentration from 5 mg/mL to 10 mg/mL. Among the tested bacterial strains, *Escherichia coli* showed comparatively higher susceptibility to the plant extracts than *Staphylococcus aureus*.

### 5.3 Minimum Inhibitory Concentration (MIC)

The Minimum Inhibitory Concentration (MIC) analysis demonstrated that ethanolic extracts of both Bitter melon and Moringa exhibited greater bacterial growth inhibition compared to aqueous extracts. Optical density (OD) values measured at 600 nm showed reduced bacterial growth with increasing extract concentration. Moringa extracts exhibited lower optical density values than Bitter melon extracts against both *Escherichia coli* and *Staphylococcus aureus*, indicating comparatively stronger antibacterial efficacy. The inhibitory effect was concentration dependent, with higher extract concentrations showing greater bacterial growth suppression.

Table 5: MIC of aqueous extracts of Bitter melon and Moringa on *Escherichia coli*

| Concentration | Bitter melon Extract (Aqueous) | Moringa extract (Aqueous) |
|---------------|--------------------------------|---------------------------|
| 10mg          | 0.50                           | 0.69                      |
| 5mg           | 0.57                           | 0.73                      |
| 2.5mg         | 0.58                           | 0.76                      |
| 1.25mg        | 0.61                           | 0.87                      |
| 0.62mg        | 0.69                           | 0.92                      |
| 0.31mg        | 0.85                           | 0.96                      |

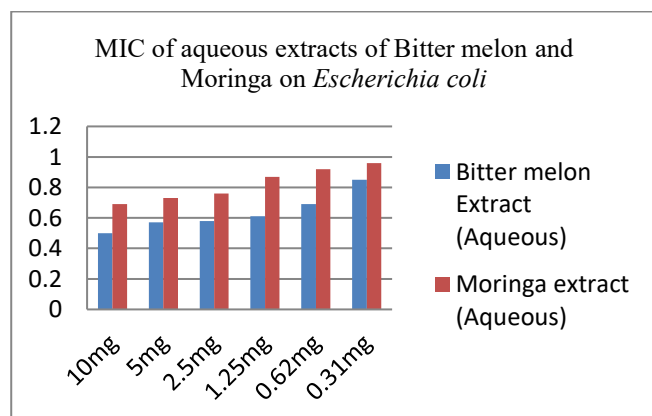


Table 6: MIC of ethanolic extracts of Bitter melon and Moringa on *Escherichia coli*

| Concentration | Bitter melon Extract (Ethanol) | Moringa extract (Ethanol) |
|---------------|--------------------------------|---------------------------|
| 10mg          | 0.69                           | 0.62                      |
| 5mg           | 0.72                           | 0.68                      |
| 2.5mg         | 0.78                           | 0.71                      |
| 1.25mg        | 0.81                           | 0.87                      |
| 0.62mg        | 0.85                           | 0.91                      |
| 0.31mg        | 0.89                           | 0.93                      |

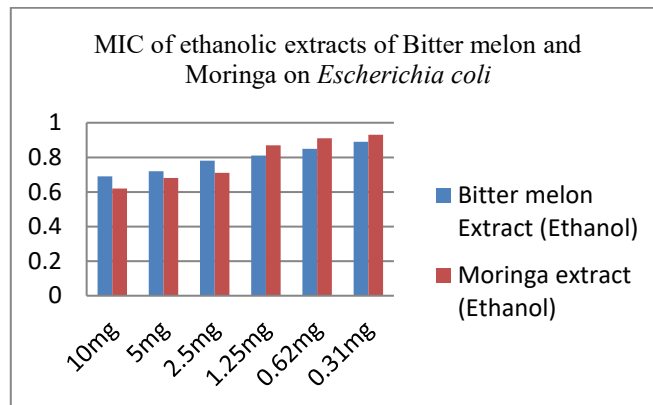


Table 7: MIC of aqueous extracts of Bitter melon and Moringa on *Staphylococcus aureus*

| Concentration | Bitter melon Extract (Aqueous) | Moringa extract (Aqueous) |
|---------------|--------------------------------|---------------------------|
| 10mg          | 0.69                           | 0.62                      |
| 5mg           | 0.72                           | 0.68                      |
| 2.5mg         | 0.78                           | 0.71                      |
| 1.25mg        | 0.81                           | 0.87                      |
| 0.62mg        | 0.85                           | 0.91                      |
| 0.31mg        | 0.89                           | 0.93                      |

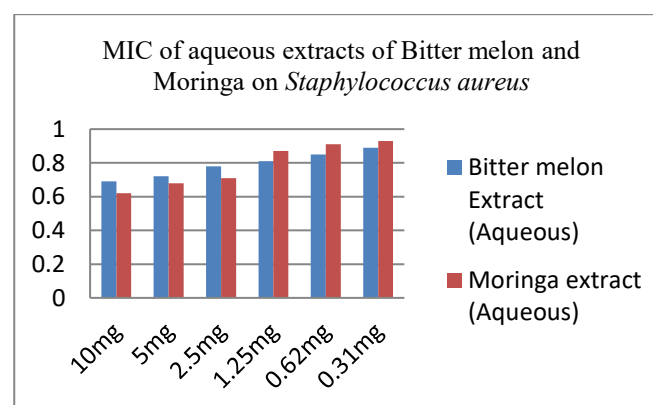
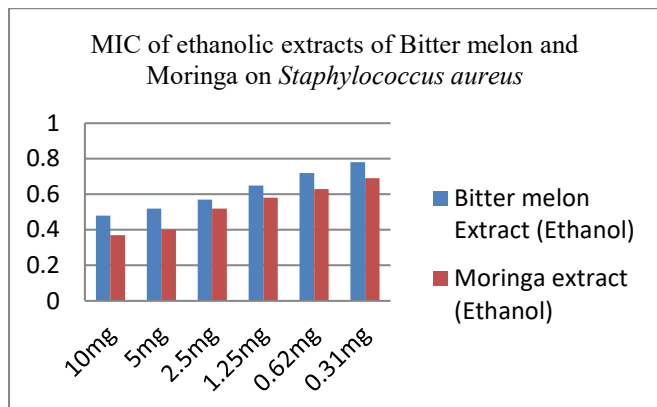


Table 8: MIC of ethanolic extracts of Bitter melon and Moringa on *Staphylococcus aureus*

| Concentration | Bitter melon Extract (Ethanol) | Moringa extract (Ethanol) |
|---------------|--------------------------------|---------------------------|
| 10mg          | 0.48                           | 0.37                      |
| 5mg           | 0.52                           | 0.40                      |
| 2.5mg         | 0.57                           | 0.52                      |
| 1.25mg        | 0.65                           | 0.58                      |
| 0.62mg        | 0.72                           | 0.63                      |
| 0.31mg        | 0.78                           | 0.69                      |



#### 5.4 Gas Liquid Chromatography (GLC) Analysis

Gas Liquid Chromatography (GLC) analysis confirmed the presence of major phytochemical constituents in both medicinal plants. Quercetin was identified as the predominant bioactive compound in Bitter melon extract, whereas Moringin was identified as the major compound present in Moringa extract. The chromatographic analysis suggested that the antibacterial activity observed in the present study maybe associated with the bioactive phytochemical constituents. The highest antibacterial activity of Moringa extract compared to Bitter melon extracts may be attributed to the comparatively stronger antimicrobial action of moringin.

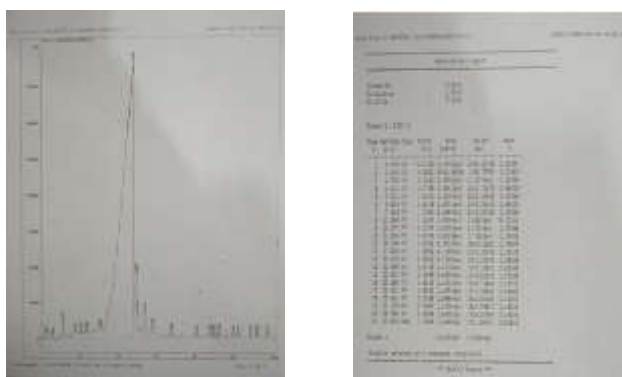


Fig. 9: GLC Analysis of Bitter Melon extract

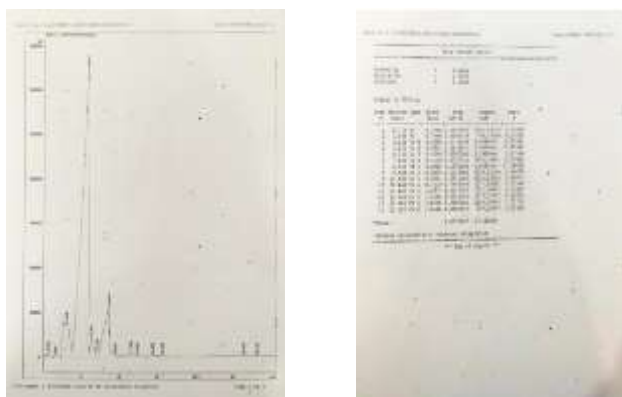


Fig. 10: GLC Analysis of Moringa extract

The results demonstrated that both medicinal plants possessed significant antibacterial activity against the tested bacterial strains. Ethanolic extracts exhibited greater antibacterial efficacy than aqueous extracts, indicating better

extraction of active phytochemicals. Comparative analysis revealed that *Moringa oleifera* L. leaf extracts showed stronger inhibitory activity against both *E. coli* and *S. aureus* than *Momordica charantia* L. extracts, although Norfloxacin produced the highest zones of inhibition. GLC analysis identified quercetin as the major phytochemical in *Momordica charantia* L. and moringin as the predominant bioactive compound in *Moringa oleifera* L., which may contribute to their antimicrobial properties. Overall, the findings suggest that both plants are promising natural sources of antibacterial compounds and could serve as potential candidates for the development of plant-based antimicrobial agents. Further in vivo studies and isolation of active constituents are recommended to validate their therapeutic applications.

#### 6. CONCLUSIONS

The present study demonstrated that both *Momordica charantia* L. and *Moringa oleifera* L. leaf extracts possess significant antibacterial activity against *Escherichia coli* and *Staphylococcus aureus*. Among the tested extracts, ethanolic extracts exhibited greater antibacterial efficacy than aqueous extracts, indicating that ethanol is a more efficient solvent for extracting bioactive phytochemicals responsible for antimicrobial activity. The antibacterial effect of both medicinal plants increased with increasing extract concentration, as confirmed by the disc diffusion assay and minimum inhibitory concentration (MIC) analysis. Comparative evaluation revealed that *Moringa oleifera* exhibited stronger antibacterial activity than *Momordica charantia* against both bacterial species. GLC analysis identified quercetin as the major phytochemical in *Momordica charantia* and moringin as the predominant bioactive compound in *Moringa oleifera*, suggesting that these constituents may contribute to the observed antibacterial effects. Although the antibacterial activity of the plant extracts was lower than that of the standard antibiotic, the findings highlight the potential of these medicinal plants as natural sources of antimicrobial agents. Further investigations involving purification of active compounds, toxicity assessment, and in vivo studies are recommended to validate their therapeutic efficacy and support the development of plant-based antibacterial formulations.

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