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Research Article

In Vitro Antifungal Activity of Okra (*Abelmoschus esculentus* L.) Leaf Extract against Different Plant Pathogenic Fungal Species

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Abstract

The antifungal efficacy of *Abelmoschus esculentus* L. (Okra) leaf extracts was investigated across four distinct solvents (Ethanolic, Methanolic, Chloroform, and Water) against five significant fungal pathogens (*Mucor sp., Rhizopus sp., Drechlera sp., Penicillium paxilli,* and *Aspergillus nigar*). The Two-Way ANOVA confirmed that the choice of Extract Type was highly significant ($P < 0.001$), while the Pathogen Type was not statistically significant ($P = 0.56137$), clearly indicating that solvent polarity is the single most critical factor determining fungicidal activity. The intermediate-polarity Ethanolic and Methanolic extracts demonstrated superior, broad-spectrum potency, yielding inhibition rates between 94.54 % and 98.33 % across all fungal genera. This high efficacy is attributed to the optimal co-extraction of key semi-polar and lipophilic antifungal phytochemicals, such as phenolics and flavonoids, which exert their effect by targeting conserved fungal structures like the cell membrane and inhibiting essential metabolic processes. Conversely, the highly polar Water extract performed poorly (62.00 % to 76.00% inhibition) due to its inability to efficiently solubilize these highly active compounds, confirming that *A. esculentus* leaves are a source of potent, broad-spectrum natural fungicides best accessed via alcoholic solvents.

Key words: *Abelmoschus esculentus*; Antifungal activity; Okra leaf extract; Natural antifungal agents; Plant-derived fungicides;

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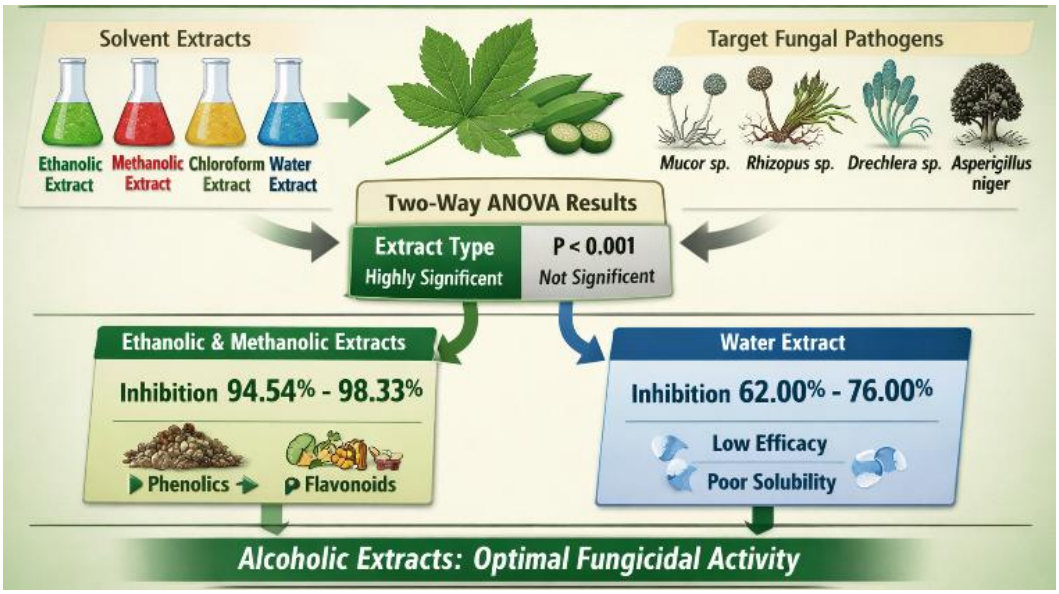
Graphical Abstract



1. Introduction

Historically, the primary method for protecting crops against fungal attacks has been the use of fungicides. Nevertheless, many currently available synthetic fungicidal agents pose significant environmental and health risks. They are often toxic, have undesirable effects on non-target organisms, and some are non-biodegradable, leading to accumulation in the soil, plants, and water, potentially affecting humans through the food chain. A major concern is the development of resistance by pathogenic fungi towards these synthetic chemicals. Consequently, there is an urgent and growing need for eco-friendly, sustainable measures for disease management.

This has spurred a renewed interest in natural products, a trend reversing the decline in research that followed the widespread adoption of synthetic agrochemicals in the 1940s. Plant-derived natural products are now recognized for their enormous potential to inspire and influence modern agrochemical research (Yoon *et al.*, 2013). Natural products offer a viable solution to the environmental challenges posed by synthetic pesticides. The presence of antifungal compounds (phytoactivities) in higher plants has long been linked to their natural disease resistance (Madihah *et al*., 2018). These plant-based compounds are particularly valuable as they are typically biodegradable, selective in their toxicity, and generally safer for the environment and consumers (Jabeen *et al*., 2018; Raduly *et al*., 2020). While research interest in using medicinal and common plants to control plant diseases is increasing, only a small fraction (about 2,400 out of over 250,000 higher plant species) has been screened for phytoactivity (Khan *et al*., 2020; Aioub *et al*.2024). Plant-based pesticides are advantageous because they are cheap, locally available, non-toxic, and easily biodegradable. Numerous studies have demonstrated that various plant species possess significant antifungal and antibacterial properties (Raphael, 2012).

The family Malvaceae includes nearly all forms of life, annual herbs to perennial trees and characterized by 243 genera and 4225 species. This family is documented as a large family and spread all over the world frequently in warmer areas. Its customarily related families i.e., Bombacaceae, Sterculiaceae, and Tiliaceae were amalgamated in the expanded family Malvaceae and alienated into 9 subfamilies including Grewioideae, Byttnerioideae, Tilioideae, Dombeyoideae, Malvoideae, Bombacoideae, Helicteroideae, Sterculioideae, and Brownlowioideae (Ah-

mad and Kumar, 2016). *Abelmoschus esculentus* L. or okra is a warm-season annual herbaceous vegetable crop that belongs to the Malvaceae (mallow) family. It is mainly grown to get its premature adolescent fresh fruits and young soft leaves used to make salads, broths, and stews. Okra crop is generally self-pollinated and has its derivation in West Africa (Oppong-Sekyere *et al*., 2011).

The genus Abelmoschus comprises ten species. Four of these species are extensively cultivated and are collectively known as okra or okro (Essilfie *et al*., 2010). These species are *A. esculentus* (L.) Moench, *A. caillei* (A. Chev.) Stevels, *A. manihot* and *A. moschatus*. But later on, the name okra or okro was restricted to *A. esculentus* and *A. caillei* (Essilfie *et al*., 2010). Okra belongs to the genus Hibiscus, which is categorized by apolar, pantaporate, and globose to spheroidal pollen grains. The wall of a completely developed pollen is composed of unremitting intine and exine, all over distributed with spines of varying height and width. The characteristics of the spine index are used to describe Malvaceous pollen and found to be the significant taxonomic feature (Essilfie *et al*., 2010).

The leaves and young fruits of okra show high antioxidant potential, have high contents of calcium and the seeds are rich in protein (20 % of dry weight) and vegetable oil (14 % of dry weight) (Roger and Fernande, 2018). The fresh fruits of okra are considered rich fonts of minerals like manganese, potassium, iodine, iron, zinc, nickel, copper, calcium and many vitamins including A, B complex, C, and K, and folic acid, and these nutrients are missing in the diet of most of the population of developing countries in the world. Newly developed fresh fruit of okra is a healthy vegetable comprising 86.1 % humidity, 2.2 % protein, 0.2 % fat, 9.7 % sugars, 1.0 % fortitude, and 0.8 % residue (Eshiet and Brisibe, 2014).

Okra is a valuable medicinal crop due to the various functions performed by different part of the plant such as, flower bud, root, stem, leaf, pod and seeds (Gemede *et al*., 2015). The fresh young pods of okra are practiced for the treatment of leucorrhea, constipation, spermatorrhea, jaundice and diabetes and the mucilaginous contents of the pods are very effective in treating gastrointestinal disorders (Akbar, 2020). Traditionally the fruits of okra have been employed for calmative, appetizer, caustic and increase production of gonadal hormones. It is also practiced for the treatment of lingering intestinal inflammation, sexually transmitted bacterial infections, urinary mucosal imbalance, bladder blockage and infections of colon (Esmaeilzadeh *et al*., 2020). The seeds of okra have been used in the treatment of cancer. Their seeds also found to be effective as fungicide (Islam, 2019). The modern studies revealed that the medicinal potential of *A. esculentus* includes antioxidant potential (Sabitha *et al*., 2012), anti-inflammatory action (Ortaç *et al*., 2018), immunomodulatory function (Chen *et al*., 2016), gastroprotective, and neuroprotective responses (Doreddula *et al*., 2014), lipid lowering potential (Islam, 2019), anticancer, and antibacterial ability (Mollick *et al*., 2014) and antidiabetic effects (Zhang *et al*., 2018). The walls of tender okra pods have some mucilaginous substances which are found to be alkaline, contributing to relieving the effect of gastrointestinal ulcers by neutralizing acids in the digestive tract. It stabilizes the levels of sugar in blood and also aid the process of absorption of sugars in blood to maintain the blood homeostasis. Mucilage present in okra founds to be very active in plasma replacement, forming tablets, and improving production and capacity of blood with a great potential to improve functionality of kidneys, assuage ailments of kidney, and diminishes protein malfunctioning (Eshiet and Brisibe, 2014).

The Okra plant (*Abelmoschus esculentus* L.), a widely cultivated vegetable crop, is known for its mucilaginous pods, leaves, and medicinal properties. Its leaves, in particular, have been used in traditional medicine, suggesting the presence of bioactive compounds. Given the escalating problems associated with synthetic fungicides, investigating the efficacy of easily accessible plant materials like Okra leaves presents a promising, low-cost, and environmentally sound alternative for crop protection.

Therefore, the present investigation was undertaken to screen the crude leaf extract of Okra (*Abelmoschus esculentus* L.) for its in vitro antifungal potency against a panel of important phytopathogenic fungi, including *Aspergillus nigar, Mucor sp., Drechlera sp., Penicillium paxilli,* and *Rhizopus* sp..

2. Material and Methods

2.1 Plant Material and Pathogen Culture

Healthy leaves of *Abelmoschus esculentus* (Okra) were collected from suitable habitats. Pure cultures of the test pathogens (*Aspergillus nigar, Mucor sp., Drechlera sp., Penicillium paxilli,* and *Rhizopus* sp.) were obtained from a recognized microbiological source. Malt Extract Agar (MEA) was used as the standard culture medium for sub-culturing the fungi.

2.2 Phytochemical Evaluation

Qualitative assessment of phytochemicals was conducted by using the protocol of Parekh and Chanda (2007) and Raphael (2012).

2.3 Antimicrobial activity

Grind the dried leaves of okra to make a fine powder and weigh 6 g powder of okra by electric balance for each solvant. Take four 500 mL conical flasks and add sample powder in it. Add 120 mL of each solvent, ethanol, methanol,chloroform and water in conical flasks. Cover the conical flask with polythene bag and tight it with rubber band and place the conical flask on orbit rotatory shaker. Leave this solution overnight at the constant speed of shaker. Take the china dish and place this in oven for 5 min and then place this in desiccator for half an hour and weigh this china dish. Take out the solution from orbit shaker and filter this solution with the help of funnel in the stand with filter paper in it, in china dish. Then filtered extract is obtained. Then place this china dish with extract in it, in an open space for air dry. After 24 hours put this china dish in an oven and then in desiccator for 30 minutes. Weigh this china dish with crude extract in it. Now add 5 mL of DMSO and scrap the crude with the help of spatula. Mix it well so that fine solution is obtained. Now place this solution in brown bottle to which light cannot penetrate. Place the bottle in safe place at room temperature.

2.4 Antifungal activity

MEA media was prepared in a flask and tightly sealed with plastic sheets and rubber bands, placed in autoclave for sterilization. Sterilization was done at 121 ^{o}C temperature and 15 psi pressure for 20 minutes. Media were removed from the autoclave and bring it to laminar air flow cabinet. Before placing media in laminar air flow cabinet, it was cleaned and sterilized with ethanol and UV light. UV light remained on for 20 minutes in laminar air flow cabinet. Two spirit lamps were placed in the laminar and used for sterilization to avoid contamination. Flask was opened and its mouth was placed at flame of lamp to ensure sterilized conditions. Before pouring media 10% ethanolic and methanolic extracts of *A. esculentus* L. leaves were added in the media separately in each flask labelled previously. Plates were slightly opened from a side to pour the media. After pouring plates were allowed to cool at room temperature so that media could be solidify. In solidified plates a single well in center of each plate was drilled with cork borer. Then previously prepared cultures were taken and a plug of culture were removed from these plates and placed in the wells made in the plates. After placing plugs, plates were placed in incubator for growth and growth was recorded as appearance of zones of inhibition after 7 days (Suwanmanee *et al*., 2014).

The percent inhibition of fungal growth was calculated by using the given formula (Vincent, 1947).

$$\mathbf{I} = \frac{C-T}{C} \times \mathbf{100}$$

In this formula, I = percent inhibition

C = Colony diameter in control

T = Colony diameter in treatment

3. Results

3.1 Pharmacological activities

Qualitative phytochemical analysis of *Abelmoschus esculentus* L. leaves was done by adopting the methodology of Jamil *et al.* (2012) and results were described in following figures and table.

Table 1: Qualitative phytochemicals screening of leaf extracts

Test name	Plant parts	Result	Inference
Saponins	Leaves	Persistent froth	++
Terpenoids	Leaves	Blue green ring appeared	++
Tannins	Leaves	Yellow Green coloration	++
Phlobatannins	Leaves	Red precipitation	+
Cardiac glycosides	Leaves	Blue green coloration	++
Anthraquinones	Leaves	Purple color	-
Flavonoids	Leaves	Yellow color appears	++
Phenolic compounds	Leaves	Green color	++

Note. (++), strongly present; (+), present; (−), absent. All tests were performed on leaf samples. Color descriptions indicate positive or negative reactions based on standard phytochemical screening methods.

3.2 Antifungal activity of leaves of *A. esculentus* L.

For this study five different fungal strains *i.e., Penicillium pexilli, Mucor* sp., *Aspergillus nigar, Dreschlera* sp. and *Rhizopus* sp. were used. All these organisms cause serious infectious diseases. Ethanolic extract of okra leaves control maximum growth of all the five fungal species. Methanolic extract of leaves of okra completely inhibit growth of *Drechslera, Penicillium paxilli, Aspergillus nigar,* and *Mucor* sp. but show slight growth of *Rhizopus* sp.

Another comparison was made between the extract in chloroform against the same five fungal strains. Chloroform extract completely control the growth of *Aspergillus nigar, Penicillium paxilli* on the other hand, it was less resistant to *Mucor* sp., *Rhizopus* sp., and *Drechslera sp.* It allows a little growth of *Mucor* sp., *Rhizopus* sp., *Aspergillus nigar*, and *Penicillium paxilli*. *Penicillium paxillin, Aspergillus nigar* and *Mucor* sp. show maximum growth on water extract of okra plant leaves**.**The antifungal activity of okra (*Abelmoschus esculentus*) extracts prepared using different solvents (ethanol, methanol, chloroform, and water) was evaluated against five pathogenic fungi, namely *Mucor sp., Rhizopus sp., Drechslera sp., Penicillium paxilli,* and *Aspergillus nigar*. Growth inhibition (%) was used as a measure of antifungal efficacy, and the results are summarized in the tabulated data.

At a concentration of 10 mg/mL, all organic solvent extracts exhibited strong antifungal activity compared to the aqueous extract. Among the tested solvents, ethanolic and methanolic extracts showed the highest growth inhibition against all fungal strains, with values ranging from 94.54 % to 98.33 %.

The chloroform extract demonstrated slightly lower but still substantial antifungal activity (90–94.54 %), whereas the aqueous extract showed the least inhibition (62–76 %).

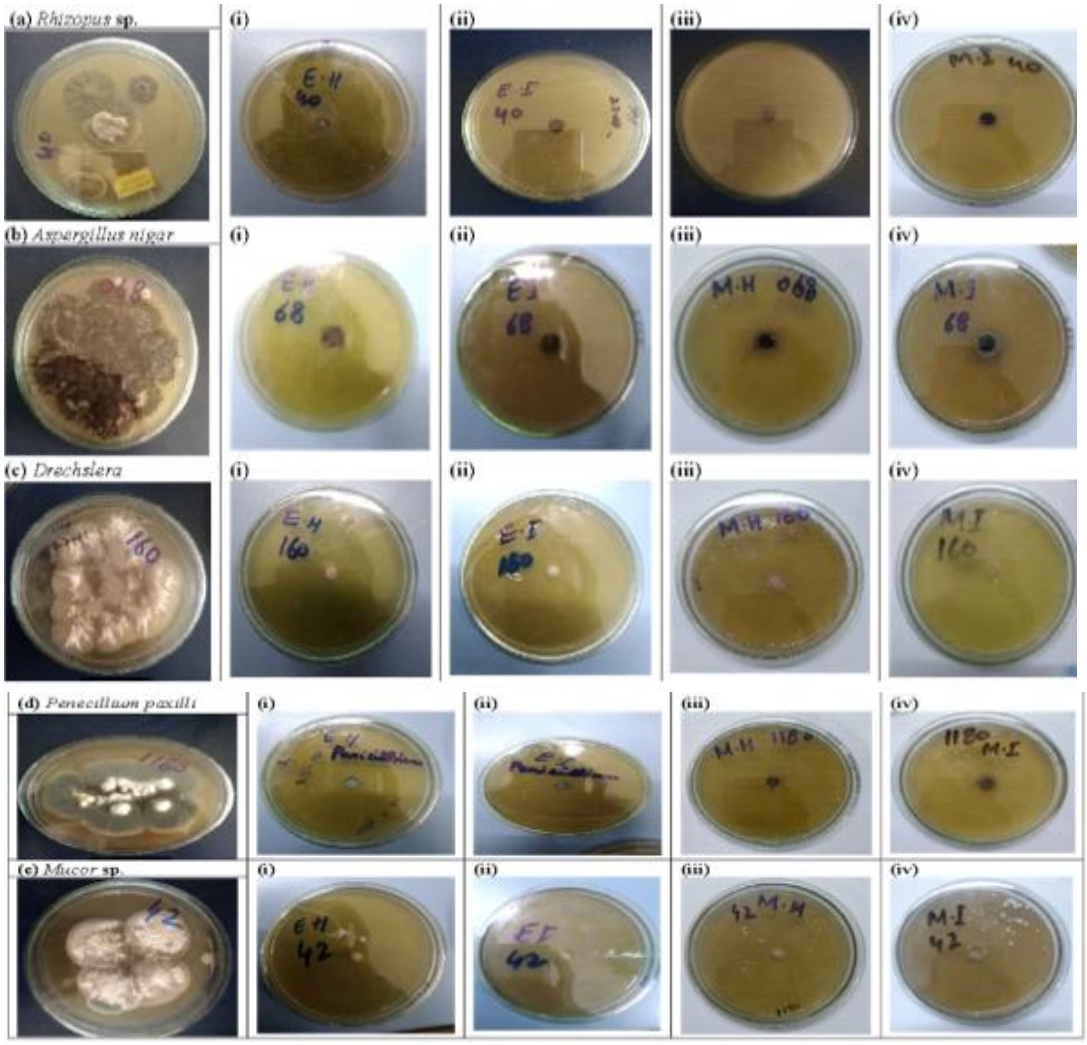


Fig 1: Illustration of the results of antifungal activity on petri plates using leaves extracts of *A. esculentus* prepared in ethanol, methanol, chloroform, and water against five species of human pathogenic fungi (*Rhizopus sp.*, *Aspergillus nigar*, *Dreschlera sp.*, *Penicillium paxilli* and *Mucor sp.*). Figure (a) petri plate showed the growth of positive control of Mucor sp. and (i-iv) depicted the effect of different extracts of control and infected plant in ethanol, methanol, chloroform, and water. (b) illustrated the growth of positive control of *Rhizopus* sp. (c) showed the growth of positive control of *Aspergillus nigar*, whereas (d) represented the growth of positive control of *Penicillium paxilli*. (e) depicted the growth of positive control of *Drechslera sp*. While all the figures numbered as (i) displayed the effect of ethanolic extract of okra leaves on all these fungal strains, whereas all the figures numbered as (ii) represented the effect of methanolic extract of okra leaves on all fungal species, figure (iii) of all fungal strains depicted the effect of chloroform extract of okra leaves on these fungal species under examination while (iv) represented the effect of water extract of okra leaves on all fungal species.

Specifically, the ethanolic extract showed maximum inhibition against *Drechslera* (98.33 %), followed by *Aspergillus* (96.66 %) and *Mucor* (96 %). Similarly, the methanolic extract exhibited the highest activity against *Aspergillus* (96.7 %) and *Penicillium* (96.36 %). The chloroform extract showed

moderate activity, with the highest inhibition observed against *Penicillium* (94.54 %). In

contrast, the aqueous extract displayed comparatively low antifungal activity, with minimum inhibition recorded against *Aspergillus* (62 %).The standard deviation and standard error values were low for ethanolic and methanolic extracts, indicating consistency and reliability of the observed antifungal effects. Higher variability was observed in the aqueous extract, suggesting less uniform antifungal efficacy.

Two-factor ANOVA without replication was applied to assess the statistical significance of differences among fungal species (rows) and solvent extracts (columns). The ANOVA results revealed that variation among columns (different extracts) was statistically significant ($F > Fcrit$, $p < 0.05$), indicating that the type of solvent used for extraction significantly influenced antifungal activity. However, variation among rows (different fungal species) was not statistically significant ($F < Fcrit$), suggesting that the extracts exhibited broadly similar antifungal effects across the tested fungi.

Discussion

The present study demonstrates that okra possesses significant antifungal potential, particularly when extracted using organic solvents. The superior antifungal activity of these extracts may be attributed to their higher efficiency in extracting bioactive phytochemicals, including phenolic compounds, flavonoids, tannins, and alkaloids, which are known for their antimicrobial properties.

The highly significant results obtained from the Two-Way ANOVA, specifically the superior performance of the alcoholic (Ethanolic and Methanolic) extracts over the Chloroform and Water extracts, can be robustly interpreted and discussed by contextualizing the findings within the known phytochemical profile and biological activity of Okra leaves. The $P < 0.001$ for the Extract Type confirms that the solvent choice is the primary determinant of antifungal potency, overshadowing the differences between the pathogens. Okra is well-documented in ethnobotany and scientific literature as a plant rich in secondary metabolites, many of which exhibit significant

Table. 2: Growth Inhibition (%) of Fungal Pathogens Treated With Different Extracts at 10% Concentration

	Growth inhibition (%)			
Pathogens	**Ethanolic Extract**	**Methanolic Extract**	**Chloroform Extract**	**Water Extract**
Mucor sp.	96	96	90	75
Rhizopus sp.	95.55	95.6	91.11	71
Drechlera sp.	98.33	98	90	72
Penicillium paxillin	94.54	96.36	94.54	7
Aspergillus nigar	96.66	96.7	91.7	62
Standard deviation	1.41	0.91	1.86,	5.54
Standard error	0.63,	0.41,	0.83,	2.47

Note. Values represent percentage growth inhibition at a 10% extract concentration. SD = standard deviation; SE = standard error. Pathogen names are presented in italics in accordance with APA guidelines.

Table. 3: **Two Way Anova showing activity of extracts against different fungal species**

SUMMARY	Ethanolic Ext	Methanolic Ext	Chloroform Ext	Water Ext	Total
		Mucor sp.			
Count	3	3	3	3	12
Sum	286.5	288.00	267.00	223.50	1065.00
Average	95.5	96.00	89.00	74.50	88.75
Variance	0.25	0.99	0.99	0.25	82.61
		Rhizopus sp.			
Count	3	3	3	3	12
Sum	285.05	285.59	272.66	211.50	1054.80
Average	95.01	95.19	90.88	70.50	87.90
Variance	0.27	0.22	0.08	0.25	113.48
		Drechlera sp.			
Count	3	3	3	3	12
Sum	294.39	291.00	267.00	214.50	1066.89
Average	98.13	97.00	89.00	71.50	88.90
Variance	0.04	0.99	0.99	0.25	124.12
		Penicillium paxillin			
Count	3	3	3	3	12
Sum	283.24	289.90	281.8	225.00	1079.94
Average	94.41	96.63	93.93	75.00	89.99
Variance	0.32	0.11	0.31	0.99	83.23
		Aspergillus nigar			
Count	3	3	3	3	12
Sum	289.66	288.15	274.7	183	1035.51
Average	96.55	96.05	91.56	61	86.29
Variance	0.26	0.39	0.26	1	237.08

antimicrobial properties (Gemede *et al*., 2015). The leaves, in particular, are known to contain a variety of bioactive compounds, and the experimental results directly reflect the efficiency with which the chosen solvents extract these compounds (Pinto *et al*., 2006; Jbeen *et al*., 2018).

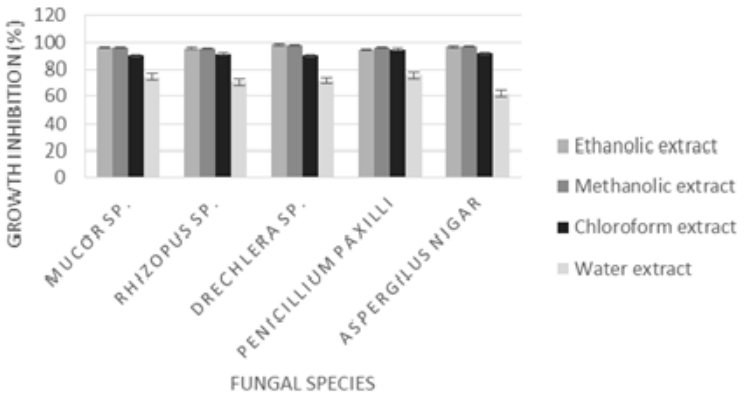


Figure 2: **Graphical representation of the Antifungal activity of okra leaves extract in different solvents**

Ethanol and methanol are polar solvents capable of solubilizing a wide range of secondary metabolites. Previous studies have reported that phenolic compounds and flavonoids disrupt fungal cell membranes, interfere with enzymatic activity, and inhibit spore germination, leading to reduced fungal growth. The consistently high inhibition percentages observed in the ethanolic and methanolic extracts support this mechanism.

The data showing 94.54 % to 98.33 % inhibition for the Ethanolic and Methanolic extracts is a direct consequence of the optimal solvent power of these semi-polar alcohols for the major antifungal compounds in Okra leaves (Adetuyi *et al.*, 2016).

Numerous studies on *A. esculentus* and other plant materials confirm that intermediate-polarity solvents (such as 80 % Methanol and 80 % Ethanol, often used in extraction) typically yield the highest total phenolic and total flavonoid contents (Adetuyi *et al*., 2016; Do *et al*., 2014). These compounds, which are the primary drivers of antifungal activity, are optimally solubilized by the intermediate polarity of the alcohol/water mixtures, adhering to the "like dissolves like" principle (Vongsake *et al*., 2013).

The high efficacy against a diverse group of fungi (Mucor, Rhizopus, Drechlera, Penicillium, Aspergillus) suggests the potent synergistic action of multiple compounds (flavonoids, tannins, etc.) (Gemede *et al.*, 2015; Wagnar and Ulrich-Merzenich, 2009). These compounds simultaneously attack the fungal cell, inhibiting key metabolic enzymes and disrupting the integrity of the cell membrane, which provides a multi-targeted and highly effective fungicidal approach (Raduly *et al.*, 2020).

The significant drop in inhibition for the Water extract 62% to 76% is explained by the polarity mismatch. While Okra is famous for its highly polar mucilage (polysaccharides) (Gemede *et al*., 2015; Deters and Steingass, 2010), these complex carbohydrates are generally less effective as potent, direct fungicidal agents compared to the smaller, more lipid-soluble phenolic compounds (Al-Fatimi and Juliana, 2021). The highly polar water extraction fails to efficiently draw out the majority of the crucial semi-polar and lipophilic antifungal components, resulting in a severely reduced fungicidal profile (Do *et al*., 2014).

The Chloroform extract (around 90 % to 94 % inhibition) is less effective than the alcoholic extracts but significantly better than water. Chloroform, being non-polar, successfully extracted the more lipophilic antifungal components, such as certain terpenoids and specific lipophilic flavonoids that reside in the cell membrane (Hossain and Shah, 2015). This level of activity confirms that some fungicidal power resides in the non-polar fraction, likely targeting the fungal membrane lipids (Pinto *et al*., 2006). The chloroform extract showed moderate antifungal activity, also due to the extraction of non-polar or moderately polar compounds such as terpenoids and sterols. Although these compounds possess antifungal properties, their overall activity appears lower than that of polar phenolics extracted by ethanol and methanol

The comparatively weak antifungal activity of the aqueous extract can be explained by the limited solubility of many antifungal phytochemicals in water. Additionally, water extracts may contain higher amounts of sugars and other inactive constituents that dilute the concentration of active compounds, resulting in reduced antifungal efficacy.

The ANOVA result indicating no statistically significant difference in sensitivity among the five tested fungal genera (P = 0. 561376) is highly significant in the context of Okra's broad-spectrum potential. The tested organisms span diverse taxonomic groups (Zygomycetes like *Mucor* and *Rhizopus*; Ascomycetes like *Aspergillus* and *Penicillium*). The uniformity of the response to the treatment, especially the highly potent alcoholic extracts, suggests that the bioactive compounds are targeting fundamental, highly conserved cellular structures and pathways common to most fungi (Raduly *et al*., 2020). The most common targets for natural antifungals are

the cell membrane, via interference with ergosterol biosynthesis, and key metabolic enzymes (Pinto *et al.*, 2006). This broad efficacy is a major advantage. Unlike many synthetic drugs that target a single, specific metabolic pathway, the complex mixture of synergistic compounds in the Okra leaf extracts makes it significantly harder for the fungi to employ resistance mechanisms, such as efflux pumps or target-site mutation, effectively against all active agents simultaneously (Sharma *et al*., 2021). The potency of the 95% inhibition suggests the extracts are delivering a fungicidal "overkill" that overwhelms any subtle innate resistance differences between the species (Rangel-Gomez *et al.*, 2020).

The ANOVA results further confirm that solvent selection plays a crucial role in determining the antifungal potential of plant extracts. The non-significant variation among fungal species suggests that okra extracts have a broad-spectrum antifungal effect, making them promising candidates for controlling a wide range of phytopathogenic fungi.

Overall, the findings of this study align with earlier reports on the antimicrobial activity of okra and other medicinal plants, reinforcing the importance of solvent optimization in phytochemical extraction. The strong antifungal activity observed, particularly in ethanolic and methanolic extracts, indicates that okra could serve as a natural and eco-friendly alternative to synthetic fungicides. However, further studies involving minimum inhibitory concentration (MIC), mode of action, and in vivo evaluations are recommended to validate its practical application.

4. Conclusion

The data conclusively establishes the Ethanolic and Methanolic extracts of Okra leaves as highly potent, broad-spectrum antifungal agents. The superior performance of these extracts is directly linked to their efficiency in extracting high concentrations of key semi-polar and lipophilic compounds, primarily phenolics and flavonoids.

These results strongly support the development of natural-product-based fungicides derived from Okra leaves for application in post-harvest protection against storage fungi (like *Aspergillus* and *Penicillium*) or for managing crop diseases caused by soil-borne pathogens (Rhizopus and Mucor). Further research should now focus on determining the Minimum Inhibitory Concentration (MIC) of the optimized alcoholic extracts to fully quantify their potency against these pathogens.

Author Contributions:

Conceptualization, AR. methodology, AR.; software, AH.; validation, AR. and AH.; formal analysis, AR.; investigation, AH.; resources, AR.; data curation, AR.; writing—original draft preparation, AR.; writing—review and editing, AH and AR.; visualization, AR.; supervision, AR.; project administration, AR.. All authors have read and agreed to the published version of the manuscript

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