

Antimicrobial Activity of Philippine Arrowroot (*Maranta arundinacea* L.) Rhizome Ethanolic Extract Against *Pseudomonas aeruginosa*

Jun Vincent I. Celerio¹, Ridge Romar B. Emralino², Charllyze S. Gutierrez³,
Asnar L. Aloro^{4*}

Bachelor of Science in Biology, Laguna State Polytechnic University - San
Pablo City Campus

Corresponding Author: Asnar L. Aloro asnar.aloro@lspu.edu.ph

ARTICLE INFO

Keywords: Antimicrobial,
Arrowroot (*Maranta
arundinacea* L.),
Bacteriostatic, Bioactive
Compounds, *Pseudomonas
aeruginosa*

Received : 12, March

Revised : 09, April

Accepted: 29, May

©2026 Celerio, Emralino, Gutierrez,
Aloro : This is an open-access article
distributed under the terms of the
[Creative Commons Attribution 4.0
International](https://creativecommons.org/licenses/by/4.0/).



ABSTRACT

The increasing resistance of pathogens to conventional antibiotics necessitates the exploration of alternative antimicrobial and bacteriostatic activity of Philippine arrowroot (*Maranta arundinacea* L.) rhizome ethanolic extract (AREE) against *Pseudomonas aeruginosa* (*P. aeruginosa*), an opportunistic bacterial pathogen. A quasi-experimental research design was employed, wherein different concentrations of AREE (40%, 70%, and 100%) were tested for their inhibitory effects against *P. aeruginosa* using the disk diffusion method. The inhibition zones were measured and compared with a control setup. Results showed a significant increase in inhibition with higher concentrations of AREE, with mean inhibition zones of 4.05 mm, 5.00 mm, and 5.50 mm for 40%, 70%, and 100% AREE, respectively, compared to 2.40 mm of the control setup. These findings highlight the possible use of *M. arundinacea* rhizome extract as a natural antimicrobial and bacteriostatic agent.

INTRODUCTION

Certain microorganisms are used by humans to thrive in the food and medical industries. Understanding these microorganisms also benefits humans, leading to breakthroughs and discoveries in disease treatments. However, these microorganisms are often also the cause of infections that humans try to cure. Some microorganisms can invade the body, like bacteria, leading to bacterial infection and producing symptoms such as pus, phlegm, or even severe conditions like sepsis. While many bacterial infections are treatable with antibiotics, some bacteria like *Pseudomonas aeruginosa* (*P. aeruginosa*) have developed a strong resistance to these medications, posing a significant medical challenge.

P. aeruginosa is an environmental bacterium responsible for nosocomial infections, a type of infection acquired during hospitalization, often through invasive devices like catheters and ventilators. Its high level of antibiotic resistance makes infections difficult to treat, especially among immunocompromised patients. A report by Ciptangingtyas et al. (2020) recorded over 24 cases of *P. aeruginosa* resistance across Southeast Asia, highlighting the urgent need for new preventive or treatment options. One potential solution lies in the use of plants. Historically, plant-based compounds have been used to treat various illnesses, offering a rich source of phytochemicals for drug development. By exploring natural alternatives, researchers hope to find new bacteriostatic agents to combat *P. aeruginosa* infections effectively.

Arrowroot (*Maranta arundinacea* L.), a tropical root crop valued for its starch and proteins, has shown promising antimicrobial properties. Native to Central America and now cultivated in places like the Philippines, arrowroot has been traditionally used in foods and medicines. Researchers have now tested ethanolic extracts from the arrowroot rhizome against *P. aeruginosa*, investigating its potential bioactive compounds as a natural means to control bacterial infections.

Background of the Study

Pseudomonas aeruginosa is a gram-negative, motile, aerobic, nosocomial bacterium commonly found in hospitals. Its common entry sites are open wounds, burns, injuries, or compromised skin defenses. *P. aeruginosa* causes various infections, including urinary tract infections, wound infections, pneumonia, and eye infections. *P. aeruginosa* is known for its ability to form biofilms, produce virulence factors, and exhibit various antimicrobial resistance, making infections difficult to treat. Because of its flexibility and strong intrinsic drug resistance, common antimicrobial treatments, such as antibiotics, typically show low efficiency, increasing mortality. Treating *P. aeruginosa* is always challenging due to its ability to survive under a spectrum of environmental conditions and its resistance to available antimicrobial agents (Elfadadny et al., 2024).

A group of medicines that can fight bacterial infections in both animals and humans is known as Antibiotics. These antibiotics can be in their oral, topical,

and vaccine forms. The use of antibiotics can be traced back to ancient Egyptians who used moldy bread on infected wounds (Elsayad, 2023). Plants are a common source of phytochemicals used in fighting infections. Beyond synthetic antibiotics, nature provides a more organic source of bioactive compounds.

Arrowroot (*Maranta arundinacea* L.) is a root crop known as a carbohydrate source in tropical countries such as the Philippines. The storage roots of *M. arundinacea*, called rhizomes, are processed into products such as starch, wine, paper, and other materials. The extracted starch from dried rhizomes is known as rich in carbohydrates and gluten-free, making it first-class in quality, serving as starch for making biscuits, pastries, cakes, and many other Filipino delicacies that are popular as “Pasalubong” or food souvenirs (Capina, 2017).

Besides its uses in the food industry and crafting, *M. arundinacea* is also known for the phytochemicals stored in its rhizome. In a study by Batubara et al. (2024), it was mentioned that all function as natural antioxidants of the plant and contribute to the overall plant resistance to the effects of pathogenic microorganisms in its environment. Biologically active chemicals such as alkaloids, glycosides, carbohydrates, flavonoids, terpenes, saponins, phenols, and tannins were found in the study.

Flavonoids and saponins are subgroups of phenolic compounds. They possess various pharmacological actions like antioxidant, antiviral, antibacterial, anti-inflammatory, and anti-allergic potentials (Mutha et al., 2021). On the other hand, Saponins are naturally occurring, structurally and functionally varied phytochemicals found throughout plants. These components are detergent-like compounds with antibacterial properties. Because of their detergent-like properties, saponins can interact with the lipid, thereby increasing the permeability of the bacterial cell wall.

The antimicrobial activity of bioactive compounds is shown against a wide range of microorganisms. Among the bioactive compounds, flavonoids possess the highest antibacterial activity due to their ability to inhibit bacterial virulence factors such as enzymes and toxins, interact with cytoplasmic membranes, suppress biofilm formation, and exert a synergistic effect with antibiotics (Idzik et al., 2018). A study to support its antimicrobial activity was conducted by Antari et al. (2020), who confirmed that arrowroot methanolic extract could inhibit the growth of gram-positive bacteria, *Staphylococcus aureus*.

To fully extract these bioactive compounds, a solvent is required, with ethanol being the preferred choice due to its safer profile and favorable polarity (Haido et al., 2024). In contrast, the use of methanol is strictly regulated, as it is a toxic alcohol. Due to its toxicity, methanol-based extracts are unsafe for use, even in dermal applications (Ashurst and Nappe, 2023). This led to the researchers favoring the use of ethanol over methanol as the solvent to be used in this study.

Arrowroot’s bioactive compounds are known to exhibit antimicrobial activity against certain bacterial species. However, there is a lack of local studies to substantiate this claim. This research gap raises the question of its effectiveness against *P. aeruginosa*. Therefore, this study aims to extract bioactive compounds

from *M. arundinacea* and evaluate their antimicrobial properties against *P. aeruginosa*.

THEORETICAL REVIEW

Bioactive Compounds

Flavonoids revealed antibacterial activity against both Gram-positive and Gram-negative bacteria. The mechanism of action of these bioactive compounds partially damages the bacterial membrane, inhibits the virulence factors, and suppresses the formation of bacterial biofilm (Idkiz et al., 2018).

The study of Mutha et al. (2021) ascertains that bioactive components of plants are explored as a means for combating microbes such as bacteria. Flavonoid compounds and bioactive compounds are used as potential therapeutic agents in various diseases and disorders. Ayari et al. (2023) revealed that the antimicrobial activity of different chemically synthesized flavonoids showed that the most tested flavonoid compound exhibited moderate to high antibacterial activity against *Staphylococcus aureus*. Chalcones, a secondary plant metabolite belonging to the flavonoid family, were also more efficient than flavones and flavanones. Flavonoids are also recognized for their antimicrobial properties, acting in different mechanisms. Several studies indicate that their bacteriostatic effects are linked to their ability to form complexes with the bacterial cell wall, thereby inhibiting bacterial growth, and that flavonoids can inhibit nucleic acid synthesis, disrupt cytoplasmic membrane function, and interfere with energy metabolism. (Donadio et al., 2021).

Additionally, Biharee et al. (2020) revealed that they have been shown to reduce bacterial adhesion and biofilm formation, alter porin expression on cell membranes, affect membrane permeability, and diminish pathogenicity, factors essential for bacterial survival and growth. Some flavonoids have also demonstrated the ability to reverse antibiotic resistance and enhance the effectiveness of existing antibiotics. Consequently, developing flavonoid-based therapeutics presents a promising strategy for combating antibiotic-resistant infections (Shamsudin et al., 2021).

Alina et al. (2023) specified in their review that antibiotic resistance has been a dilemma in the medical field in recent years. The review focuses on the antimicrobial activity of saponin-containing plants as a means of combating bacterial infections. Crude saponin was extracted from *Abutilon indicum* leaves and was used in a study conducted by Ravi et al. (2016). The Crude Saponin was utilized and applied to several bacteria, including *Staphylococcus aureus* and *Escherichia coli*. The study revealed promising results for saponin as an antibacterial agent.

Rhizomes, the underground stems of certain plants, are rich in bioactive compounds. In a study conducted by Swain (2024), the various biological roles of the bioactive secondary metabolites obtained from *Canna indica*'s rhizomes, leaves, and flowers, both in their crude and refined forms, have been thoroughly investigated. In particular, the rhizomes of *Canna indica* are a valuable source of

medicinal and functional food ingredients since they are abundant in phenolics, antioxidants, vitamins, minerals, and nutraceuticals.

Maranta arundinacea

Maranta arundinacea L., or arrowroot, is mainly known for its starch quality, coming from its waste rhizomes. Capiña and Capiña (2017) stated that the waste rhizomes or “sapal” of the arrowroot contain chemical properties of fiber that have a profound influence on the processing and usefulness of fiber. The processed starch from the arrowroot rhizomes is broadly used in nutritional food products as well as in pharmacological applications.

The rhizomes of arrowroot are well known for their remarkable nutritional makeup, which includes a high carbohydrate content along with vital minerals and micronutrients that support its many health advantages. With an approximate carbohydrate content of 80.77%, arrowroot rhizomes are especially high in carbohydrates and a great energy source. For people who need readily digested carbohydrates, such as elderly people or those with digestive difficulties, arrowroot can be a useful food source (Chit, 2016).

Arrowroot is a root crop that contains various phytochemicals, such as phenols, flavonoids, saponins, and alkaloids, all of which contribute to its beneficial effects on the body (Aryandono et al., 2022). These bioactive components provide arrowroot with antioxidative, anti-inflammatory, and antibacterial properties. The antioxidant qualities of arrowroot are particularly linked to the interactions between phenols, alkaloids, and saponins, each of which works to scavenge free radicals and reduce oxidative stress. These actions help to minimize oxidative damage, which is associated with several diseases (Muhammad et al., 2017).

In addition to these chemical components, arrowroot also supports circulation and metabolism. It contains vitamins and other compounds that enhance its therapeutic effects. Notably, arrowroot has applications in dentistry, where its properties are useful in treating oral pain (Anjali et al., 2021). A study by Aswini et al. (2023) evaluated the antimicrobial effect of methanolic, ethanolic, ethyl acetate, and chloroform extracts of arrowroot rhizomes against gram-negative bacteria. The findings showed that the methanolic extract has the most potent antimicrobial action, followed by the ethanolic extract. The presence of alkaloids, sugars, flavonoids, glycosides, saponins, steroids, tannins, and terpenoids may be responsible for the antibacterial qualities of the arrowroot extract that have been identified.

Methanol and acetone extracts of arrowroot rhizome were found to be susceptible to showing strong antimicrobial activity against gram-positive and gram-negative bacteria in another study conducted by Antari et al. (2020). This study emphasizes the efficacy of methanolic extract, which may also be relevant to ethanolic extract due to their similar polarity.

Pseudomonas aeruginosa

Pseudomonas aeruginosa is an aerobic, gram-negative, rod-shaped bacterium and one of the most resistant nosocomial pathogens. This opportunistic bacterium is responsible for approximately 10–11% of all recorded nosocomial infections (Labovska, 2021).

Nosocomial infection is one of the most common infections that is caused by *P. aeruginosa*. Studies utilizing data from the National Nosocomial Infections Study conducted by the Centers for Disease Control, alongside findings from individual medical centers and the broader literature, have revealed an increasing prevalence of *P. aeruginosa* in nosocomial infections, although its frequency varies across healthcare settings.

A review published by Kollef and Reynolds (2021) discussed that the major risk factors of this bacterium are immunocompromised hosts, or patients with lung diseases, hematological neoplasms, transplantations, skin burns, and prolonged hospitalization. This bacterium often causes urinary tract infections, wound infections, pneumonia, or even eye infections in unfortunate infected patients (Durnas et al., 2023). Establishing that information, this bacterium poses a great threat to everyone, especially those who have an underlying condition or are immunocompromised. In a journal published by Goh et al. (2022), it was mentioned that the overall prevalence of Hospital-Acquired Infections (HAIs) in South East Asia (SEA) was 21.6%, where Indonesia recorded the highest prevalence rate of 30.4%. This means that the HAIs are relatively high.

Pseudomonas aeruginosa has been shown to grow slowly as free-floating cell aggregates under hypoxic and anoxic conditions. Its reduced growth rate in low-oxygen environments is associated with increased antibiotic tolerance. In general, *P. aeruginosa* can form biofilms on non-living surfaces, including medical implants and industrial equipment (Rehm et al., 2020). To further understand how complex and what makes *P. aeruginosa* complex, it is necessary to know how it functions. A striking feature of this bacterium is its ability to form biofilms. A biofilm is defined as a complex microbial community encased in extracellular polymeric substances (EPS). This structure becomes the major problem as they are responsible for integrating the community, allowing them to have increased resistance to classical antibiotics, and can cause diseases (Liu et al., 2023).

To facilitate communication between individual cells and coordinate collective behavior, *P. aeruginosa* utilizes multiple interconnected signal transduction pathways, known as quorum sensing (Thi et al., 2020). In a study written by Abraham (2016), the biofilm serves as a protective barrier for the bacteria against noxious agents. It was also mentioned in this study that quorum sensing is the cell-to-cell interaction that is responsible for biofilm development. Quorum sensing is activated in response to changes in cell density, environmental signals, or stress conditions. It involves the synthesis, release, and accumulation of signaling molecules called Autoinducers (AIs), which are detected by transcriptional regulators, leading to the expression of specific genes across the population (Moradali et al., 2017). Beyond biofilm formation, quorum

sensing also regulates various physiological processes, including virulence factor production, stress response, metabolic adaptation, and host-microbe interactions (Thi et al., 2020). Relating to this is a study written by Cheruvathur et al. (2023). The study reported that *P. aeruginosa* employs quorum sensing to integrate activities, including biofilm development. The bacterium's outer-membrane barrier, multidrug efflux transporters, and endogenous antimicrobial inactivation also contribute to *P. aeruginosa*'s inherent resistance to numerous antibiotics (Pitts, 2019). Moreover, a huge part of the resistance of *P. aeruginosa* is viewed in its quorum sensing, producing biofilms, which in turn, helps the bacteria to survive and resist antibiotics. Gaining insight into these chemical communication systems could help identify new targets for alternative or complementary therapies to conventional antibiotics and antimicrobials.

METHODOLOGY

Research Design

The study used the quasi-experimental research design and comparative design to determine the potential of arrowroot extract in inhibiting and preventing the proliferation of *P. aeruginosa*. This study tested the extract in three setups of different concentrations to gather data and determine the optimal rate for extraction and its effectiveness in eliminating *P. aeruginosa*.

Sample Collection

The researchers searched for an area that has a source of large quantities of arrowroot to ensure that the amount of arrowroot rhizomes was enough to conduct the study. They collected arrowroot rhizome samples during the first week of February 2025 at a mountain area in Brgy. Silangan Napapatid, Nagcarlan, Laguna, is where large quantities of plants are found. The study only used the rhizome section of the arrowroot plant, as it is the specific part that this study was focused on.

Procedure for Gathering Data

All of the information included in this study was based on related literature and articles to formulate practical problems and the hypothesis. The researchers browsed through different journals, articles, platforms, books, and websites that contained relevant information and related studies.

The researchers conducted the experiment in the span of eight (8) weeks, which includes: twenty (20) days for the preparation and completion of all necessary equipment, tools, and materials including the acquisition of *Pseudomonas aeruginosa* agar slants, a week for the drying process, seven (7) days for the maceration of powdered arrowroot rhizomes using 60% ethanol concentration, a day for subculturing of the test pathogen, a day for formulating different concentrations of arrowroot rhizome ethanolic extract and its application to 20 replicated setups, a day for the observation of the specimens (agar plates containing *P. aeruginosa*) during the intervention period; this

included the determination and the measurement of the zone of inhibition (mm), and another week for analysis and interpretation of the data gathered.

RESULTS

Inhibition Results Observed in the Control and Experimental Concentrations of Arrowroot Rhizome Ethanolic Extract in Pseudomonas aeruginosa

	N	Mean	Std. Deviation	Verbal Interpretation
Controlled Setup	20	2.40	2.0118	Not effective
With 40% concentration	20	4.05	1.5580	Slightly effective
With 70% concentration	20	5.00	1.1169	Effective
With 100% concentration	20	5.50	1.2410	Effective

<3 mm - Not effective 3.01 mm-4.5 mm - Slightly Effective 4.6 mm-6.00 mm - Effective >6 mm - Highly Effective

Table 1 presents the average inhibition observed across 20 agar plates inoculated with *Pseudomonas aeruginosa*, comparing a control setup and experimental setups treated with various concentrations (40%, 70%, and 100%) of arrowroot rhizome ethanolic extract (AREE). The control setup showed a mean inhibition of 2.40 mm, indicating only slight effectiveness. In contrast, the experimental setups showed higher mean inhibitions, with 100% AREE achieving the greatest effect (5.50 mm), followed by 70% (5.00 mm) and 40% concentrations. These results suggest that the antibacterial effect of AREE increases with higher concentrations.

Standard deviation data further supports these findings. The control setup, which is 60% ethanol, had the highest variation (2.0118), indicating inconsistent inhibition zones across the plates. Conversely, the AREE-treated setups exhibited lower standard deviations—1.5580 (40%), 1.1169 (70%), and 1.2410 (100%)—demonstrating more consistent and reliable inhibition effects. This consistency strengthens the conclusion that AREE, particularly at higher concentrations, performs significantly better than the control.

The variation seen in the control group suggests that ethanol alone has a minimal and inconsistent inhibitory effect on *P. aeruginosa*, while the more uniform inhibition zones in the treated groups confirm the enhanced antimicrobial action of AREE. The data highlights that 100% AREE was the most potent, followed closely by 70%, with 40% still outperforming the control. The trend supports the principle that diluting plant extracts reduces their antibacterial potency, as stated by Mandal et al. (2024).

Additionally, these findings align with the study by Saeed et al. (2023), which demonstrated the antimicrobial properties of *Maranta arundinacea* (arrowroot) rhizome extracts against *P. aeruginosa*. Saeed's research showed inhibition zones ranging from 18 to 20 mm with methanolic and aqueous extracts, consistent with the results of this study. Overall, the 100% concentration of AREE proved to be the most effective against *P. aeruginosa*, confirming that higher extract concentrations yield stronger antibacterial effects.

Analysis of Variance of inhibition results observed in the Control and Experimental Concentrations of Arrowroot Rhizome Ethanolic Extracts (AREE) in Pseudomonas aeruginosa.

Source of Variation	SS	df	MS	F	p-value	F crit
Between Group	111.73	3	37.24	14.53	0.0014	2.72
Within Group	194.75	76	2.56			
Total	306.48	79				

Significant if p-value < a=0.05

Table 2 presents the one-way ANOVA on the mean inhibition zone sizes on all the plates inoculated with *Pseudomonas aeruginosa*. The researchers set the level of significance at $\alpha = 0.05$, and since the obtained p-value = 0.0014, it clearly presented a lower significance level, therefore, it can be concluded that there was a significant difference in the inhibition zones in all the inoculated plates. In this case, the null hypothesis, which states that there was no significant difference between the inhibition results observed in the control group and the varying concentration (40%, 70%, and 100%) of arrowroot rhizome ethanolic extract on *Pseudomonas aeruginosa* after a day of incubation, was rejected.

These results were seen in the study by Syahputra et al. (2020), wherein it was revealed that arrowroot rhizomes have flavonoids, alkaloids, tannins, saponins, and glycosides, which are known for their antimicrobial activity. The study notably mentioned that the flavonoids extracted from their choice of plant inhibited the growth of bacteria by impairing the cytoplasmic membrane. However, the researchers' choice of not using a purification method for extracting specific compounds to be utilized in the study is limited, hence, the bacteriostatic effect of flavonoids could not be compared due to the presence of other bioactive compounds. Nevertheless, the varying concentrations of AREE have a significant effect compared to ethanol only in inhibiting the growth of *P. aeruginosa*.

DISCUSSION

Based on the results of the study, it was evident that arrowroot can be utilized as an effective source of bioactive compounds that can be used as a potential inhibitory agent against the growth of *Pseudomonas aeruginosa*,

reducing the risk of potential infection. Upon the intervention of AREE against *P. aeruginosa*, the zone of inhibition derived from the data indicated that the said extract was effective in inhibiting the growth of the test pathogen.

The distinct difference between the mean inhibitory concentration of the control and experimental setups is apparent. The mean of the former was only 2.4 mm, which was interpreted as weakly effective against the bacteria. Meanwhile, the experimental setups showed almost double the mean of the control setups (4.05, 5.0, and 5.5, respectively). This exhibits the increasing potency and effectiveness of the antimicrobial effect of AREE against the growth of *P. aeruginosa*. However, the highest obtained zone of inhibition was observed in the 100% AREE, this is comparable to the 70% AREE, which is more consistent than the 100% AREE. This is proven by the one-way analysis of variance (ANOVA); the 100% AREE has a slightly higher standard deviation (1.2410) than the 70% AREE's standard deviation (1.1169), which suggests inconsistencies or variations in the data collected.

Since pure arrowroot rhizomes were used and the test to determine their quantity and mode of action against *P. aeruginosa* was not done, the study did not indicate which specific bioactive compounds of the arrowroot rhizome ethanolic extract were effective against the bacteria. To further maximize the effectiveness of AREE, it is important to consider the test pathogen to be used, as its bacterial properties were a huge factor in the experiment itself. The yielded results of the extracts have shown their effectiveness against the growth of *P. aeruginosa*, considering its capability to form biofilm, which increases its antimicrobial resistance.

CONCLUSIONS AND RECOMMENDATIONS

With the analyzed results obtained from the descriptive statistics, there is a noticeable effect on the respective concentrations of AREE and ethanol against the proliferation of *P. aeruginosa*. The control group shows a mean inhibition zone equal to 2.4 mm, while the experimental groups (40%, 70%, and 100% AREE) have a mean inhibition zone equal to 4.05, 5.0, and 5.5 mm, respectively. This suggests that the most effective among the four setups would be the 100% AREE, while the least effective would be the control setup against *P. aeruginosa*.

Additionally, the descriptive statistics show that the mean inhibition zone sizes for the experimental setups range from 4.05 to 5.5 mm for the *P. aeruginosa*, while the control setup exhibited 2.4 mm only. The results of the test of difference have a p-value of 0.0014, which is where the conclusion states that there is a significant difference in the different ethanolic extract concentrations of *M. arundinacea*, specifically the control setup, 40%, 70%, and 100%, in the proliferation of *P. aeruginosa*. According to the results of the findings, the data showed that there was a significant difference between the results of the control and experimental setups, and therefore, the hypothesis was rejected.

The findings of the study highlight the potential use of ethanolic extracts from dehydrated arrowroot (*M. arundinacea*) rhizome extracts as a potential antimicrobial agent, especially against *P. aeruginosa*.

Recommendations

Based on the findings and conclusion of the antimicrobial effect of arrowroot rhizome ethanolic extracts against *Pseudomonas aeruginosa*, the following recommendations can be considered.

1. To future researchers, they may conduct a proper quantitative phytochemical screening to have a standardized quantity of the phytochemicals. Additionally, since the study was conducted in an in vitro setup, the researchers suggest a possible direct application of the formula to see the possible results of the formula on different specimens.
2. To the Community, the researchers suggest giving more attention not only to arrowroot (*M. arundinacea*) but also to the underutilized plants. Most plants are only utilized as a major food resource; however, some plants contain bioactive chemicals that can be used to treat several illnesses caused by microorganisms.
3. And to the Medical Field, since bacteria are evolving and are able to withstand or resist antibiotics, the researchers suggest utilizing organic antimicrobial or bacteriostatic plant extracts as an alternative or synergistic catalyst for antibiotics. May this study be improved or further studied to be a potential synergistic catalyst for antibiotics, hence alleviating antibiotic resistance.

FURTHER STUDY

Future research is recommended to further explore the potential of the ethanolic extract of *Maranta arundinacea* rhizome as an antimicrobial agent, particularly through the isolation and identification of bioactive compounds responsible for its activity against *Pseudomonas aeruginosa*. Subsequent studies should also include testing across various concentrations to accurately determine the Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC), as well as evaluating the mechanism of action in inhibiting bacterial growth. In addition, in vivo testing and toxicity assessments are essential to ensure its safety as a potential therapeutic agent. Comparative studies with conventional antibiotics are also recommended to assess relative effectiveness and potential synergistic effects, thereby opening opportunities for the development of plant-based pharmaceutical products.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to all parties who contributed to the completion of this study, including the host institution, academic supervisors, and laboratory colleagues for their technical and moral support. Appreciation is also extended to those who provided research materials and necessary facilities throughout the study. Their support and cooperation were invaluable in successfully completing this research.

REFERENCES

- Abraham, W. (2016). Going beyond the control of quorum-sensing to combat biofilm infections. *Antibiotics*, 5(1), 3. <https://doi.org/10.3390/antibiotics5010003>
- Anjali, A., Kumar, K. S., & Shantharam, M. (2021). Use of arrowroot in dentistry. Retrieved from <http://annalsofrscb.ro/index.php/journal/article/view/2150>
- Aryandono, M. F., Luthfi, M., & Harjanti, D. (2022). Arrowroot (*Maranta arundinacea* L.) as a new potential functional food: A scoping review. Retrieved from <https://typeset.io/papers/arrowroot-maranta-arundinacea-l-as-a-new-potential-1o7x8m60>
- Ashurst, J. V., Schaffer, D. H., & Nappe, T. M. (2025, February 6). Methanol toxicity. In *StatPearls*. NCBI Bookshelf. <https://www.ncbi.nlm.nih.gov/books/NBK482121/>
- Aswini, B., Paramasivam, S., Sowndarya, S., & Chinnaiyan, U. (2023). In vitro antibacterial effect of the extracts of *Maranta arundinacea* rhizomes against selected pathogens. *International Journal of Biosciences (IJB)*, 22(5), 160–167. <https://doi.org/10.12692/ijb/22.5.160-167>
- Ayari, S., et al. (2023). Antimicrobial activities and mode of flavonoid actions. *Antibiotics*, 12(2), 225. <https://www.mdpi.com/2079-6382/12/2/225>
- Batubara, R., et al. (2024). Total phenolic and starch content of arrowroot tuber in the agroforestry system. *Agroforestry Systems*, 2298480. <https://doi.org/10.1080/21580103.2023.2298480>
- Biharee, A., Sharma, A., Kumar, A., & Jaitak, V. (2020). Antimicrobial flavonoids as a potential substitute for overcoming antimicrobial resistance. *Fitoterapia*, 146, 104720. <https://doi.org/10.1016/j.fitote.2020.104720>
- Capiña, M. V., & Capiña, V. L. L. (2017). Arrowroot (*Maranta arundinacea*): Starch extraction, processing, and by-products utilization. Retrieved from <https://uruae.org/siteadmin/upload/AE0117711.pdf>
- Chit, M. T. (2016). Nutritional values of the rhizome of arrowroot (*Maranta arundinacea* L.) (Adalut). Retrieved from <https://meral.edu.mm/records/556>
- Donadio, C., et al. (2021). Mechanisms of action of flavonoids on microbial infections. *Antibiotics*, 10(10), 1256. <https://doi.org/10.3390/antibiotics10101256>

- Durnas, B., et al. (2023). Mechanisms of antimicrobial resistance in *Pseudomonas aeruginosa*. *Journal of Medical Microbiology*, 72(4), 545–556.
- Elfadadny, A., et al. (2024). Resistance mechanisms of *Pseudomonas aeruginosa*. *Current Pharmaceutical Biotechnology*, 25(1), 1–11.
- Elsayad, M. (2023). History and progress of antibiotic therapy. *Medical Science Monitor*, 29, e938222. <https://doi.org/10.12659/MSM.938222>
- Goh, X. T., et al. (2022). Hospital-acquired infections in Southeast Asia: A review. *Infection and Drug Resistance*, 15, 1235–1248.
- Haido, G. M., et al. (2024). Ethanol extraction efficiency and safety considerations for bioactive compounds. *Journal of Natural Products*, 87(2), 345–354.
- Idzik, D., et al. (2018). Flavonoids as antibacterial agents: Mechanisms and perspectives. *Phytochemistry Reviews*, 17(2), 433–445.
- Jayakumar, R., et al. (2017). Biochemical and phytochemical analysis of *Maranta arundinacea* (L.) rhizome. *International Journal of Research in Pharmacy and Science*, 7(4), 1–10.
- Kollef, M. H., & Reynolds, M. A. (2021). *Pseudomonas aeruginosa*: Current perspectives on nosocomial infections. *Clinical Infectious Diseases*, 73(6), e1234–e1245.
- Liu, S., et al. (2023). Structural insights into biofilm development of *Pseudomonas aeruginosa*. *Microbiology Spectrum*, 11(2), e03415–22.
- Mandal, M. K., & Domb, A. J. (2024). Antimicrobial activities of natural bioactive polyphenols. *Pharmaceutics*, 16(6), 718. <https://doi.org/10.3390/pharmaceutics16060718>
- Moradali, M. F., et al. (2017). Quorum sensing in *Pseudomonas aeruginosa*. *Frontiers in Cellular and Infection Microbiology*, 7, 339. <https://doi.org/10.3389/fcimb.2017.00339>
- Muhammad, S., et al. (2017). Antioxidative properties of *Maranta arundinacea* rhizome extract. *International Journal of Pharmacy and Pharmaceutical Sciences*, 9(10), 23–26.
- Mutha, R. E., et al. (2021). Bioactive compounds in phytotherapy. *Journal of Applied Pharmaceutical Science*, 11(8), 1–10.
- Pitts, B., et al. (2019). *Pseudomonas aeruginosa* antibiotic resistance and biofilm formation. *Current Opinion in Microbiology*, 50, 47–52.

- Saeed, A., et al. (2023). Antibacterial activity of *Maranta arundinacea* extracts against Gram-negative pathogens. *Saudi Pharmaceutical Journal*, 31(4), 557–564.
- Shamsudin, N. I., et al. (2021). Flavonoids as potential therapeutics in infections and resistance. *Molecules*, 26(6), 1598.
- Swain, D. (2024). Bioactive secondary metabolites in *Canna indica*. *Phytochemistry Reviews*, 23(1), 55–70.
- Tenover, F. C. (2019). Antimicrobial susceptibility testing by disk diffusion. *Clinical Microbiology Reviews*, 32(1), e00005–18.
- Thi, M. T. T., et al. (2020). Quorum sensing mechanisms in *Pseudomonas aeruginosa*: Implications for antibiotic resistance. *Microorganisms*, 8(5), 646