International Journal of Science and Engineering and Technology (IJSE)
Maiden Edition
www.federalpolyoko.edu.ng
Volume 1; Issue 1; July 2025; Page No. 56-63.

HARNESSING THE PHYTOCHEMICAL PROPERTIES OF *BRYOPHYLLUM PINNATUM* FOR THE DEVELOPMENT OF PLANT-BASED ANTIBACTERIAL SOAP IN NIGERIA

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Abstract
Bryophyllum pinnatum is a medicinal plant widely recognized for its therapeutic properties, including antimicrobial activity. This study explored its phytochemical composition, antibacterial potential, and application in herbal soap formulation. Fresh leaves of *B. pinnatum* were extracted using ethanol, and qualitative phytochemical screening was performed to detect secondary metabolites. Antibacterial activity was evaluated against *Escherichia coli*, *Staphylococcus spp.*, and *Pseudomonas aeruginosa* using the agar well diffusion method. The extract demonstrating the highest activity was incorporated at 3% w/w into a cold-process soap base post-saponification to preserve bioactivity. Physical properties and pH of the formulated soap were assessed. Phytochemical analysis revealed the presence of alkaloids (+++), flavonoids (++), tannins (++), terpenoids (++), glycosides (+), saponins (+), and phenols (+). The ethanol extract exhibited concentration-dependent inhibition against the tested bacteria, with the highest activity observed against *Staphylococcus spp.* The herbal soap maintained a stable texture, skin-compatible pH, and retained antibacterial activity. Comparative evaluation showed superior efficacy over selected commercial herbal soaps. The study demonstrates that *B. pinnatum* leaf extract possesses significant antibacterial activity and can be effectively incorporated into herbal soap formulations. These findings highlight its potential as a natural antimicrobial agent for personal hygiene products, with implications for reducing reliance on synthetic additives.

Keywords: *Bryophyllum pinnatum*, phytochemicals, antibacterial activity, herbal soap, and natural product formulation.

1.0 INTRODUCTION

In recent years, there has been a growing global interest in the use of plant-based products for therapeutic, hygienic, and cosmetic purposes. This trend is largely driven by concerns over the safety, cost, and environmental sustainability of synthetic chemicals commonly found in personal care products (Akinmoladun *et al.,* 2022). Among these plant-based resources, *Bryophyllum pinnatum* (commonly called "Miracle Leaf" or "Life Plant") has gained attention for its broad range of ethnomedicinal uses. Traditionally, the plant has been employed in the management of infections, wounds, inflammatory conditions, and skin ailments in various African and Asian communities (Okoye *et al.*, 2020).

B. pinnatum contains a diverse array of phytochemicals, including flavonoids, tannins, alkaloids, saponins, phenols, and glycosides, which have been linked to antimicrobial, anti-inflammatory, and antioxidant activities (Eze *et al.,* 2021). These bioactive compounds disrupt microbial cell membranes, inhibit enzyme activity, and interfere with the metabolic processes of pathogenic organisms (Aladejana *et al.*, 2019). Given the increasing threat of antibiotic resistance and the growing demand for safe antimicrobial alternatives, there is a strong rationale for harnessing the phytochemical potential of *B. pinnatum* in the formulation of antibacterial products such as herbal soaps.

In Nigeria, antibacterial soaps are widely used as a preventive measure against skin infections caused by bacteria such as *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*. However, many commercially available products contain synthetic additives, including triclosan and parabens, which have been associated with environmental toxicity and potential health risks (Olowokere *et al.,* 2023). Plant-derived antibacterial soaps offer a safer, eco-friendly alternative that can be locally produced at low cost, thereby reducing dependency on imported products and promoting local economic empowerment.

Harnessing *B. pinnatum* for soap formulation aligns with the World Health Organization's (WHO) advocacy for the integration of traditional medicinal plants into public health strategies, particularly in developing countries where access to affordable healthcare remains limited (WHO, 2020). This study seeks to evaluate the phytochemical constituents of *B. pinnatum*, assess its antibacterial activity against common pathogenic bacteria, and develop a plant-based antibacterial soap suitable for use in Nigeria.

2.0 REVIEW OF RELATED LITERATURE

Conceptual Framework

The search for plant-based antimicrobial agents has intensified in recent years due to the rising prevalence of antibiotic-resistant pathogens and the environmental concerns associated with synthetic chemicals. *Bryophyllum pinnatum,* commonly referred to as "miracle leaf" or "life plant," belongs to the family Crassulaceae and has been widely recognized for its ethnomedicinal applications in Africa, Asia, and South America (Okoye *et al*., 2020). In Nigeria, the plant has been traditionally used for wound healing, infection management, and as an anti-inflammatory remedy (Eze *et al*., 2021). The leaves are rich in secondary metabolites such as flavonoids, alkaloids, tannins, and saponins, which are known to possess significant antibacterial activity (Aladejana *et al.,* 2019).

The integration of *B. pinnatum* phytochemicals into antibacterial soap formulation represents an innovative approach to harnessing indigenous plant resources for public health purposes. The rationale is to produce effective antimicrobial cleansing products that are biodegradable, environmentally friendly, and accessible to rural communities.

Phytochemical Composition of Bryophyllum pinnatum

Phytochemical analysis of *B. pinnatum* has revealed a diverse range of bioactive compounds with documented antibacterial activity. Alkaloids, for example, interfere with bacterial cell wall synthesis, while flavonoids inhibit nucleic acid synthesis and disrupt microbial membranes (Komolafe *et al.,* 2022). Saponins exert antimicrobial effects by increasing the permeability of bacterial cell membranes, leading to leakage of intracellular contents (Akinmoladun *et al*., 2022). Okoye *et al.* (2020) reported that ethanol and methanol extracts of B. pinnatum leaves contained high concentrations of flavonoids, phenols, and tannins, with notable antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*. Similarly, Eze *et al.* (2021) observed that aqueous extracts of the plant inhibited the growth of both Gram-positive and Gram-negative bacteria, suggesting broad-spectrum antimicrobial potential.

Antibacterial Properties of *B. pinnatum*

Numerous in vitro studies have confirmed the antibacterial efficacy of *B. pinnatum*. A study by Aladejana *et al*. (2019) demonstrated that methanolic extracts of the plant showed significant zones of inhibition against *Pseudomonas aeruginosa*, *Bacillus subtilis*, and *Klebsiella pneumoniae*. This supports its traditional use in treating wound infections and skin disorders. Akinmoladun *et al.* (2022) emphasized that plant-derived antimicrobials, such as those from *B. pinnatum*, could serve as safer alternatives to synthetic antibacterial agents, which often cause environmental toxicity. Additionally, the bioactive compounds in *B. pinnatum* are less likely to contribute to antimicrobial resistance due to their multi-target mechanisms of action (Olowokere *et al*., 2023).

Plant-Based Antibacterial Soap Development

The formulation of plant-based antibacterial soaps involves incorporating plant extracts into a saponification matrix to produce cleansing products with antimicrobial functions. The World Health Organization (WHO, 2020) recommends promoting the use of natural antimicrobials in hygiene products, particularly in developing countries where access to commercial antiseptics may be limited. Incorporating

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B. pinnatum into soap production offers several benefits. First, it can reduce reliance on synthetic antibacterial agents such as triclosan, which have been linked to environmental contamination (Olowokere *et al.*, 2023). Second, it provides an affordable and sustainable hygiene option for rural households. Third, the integration of indigenous medicinal plants into consumer products strengthens the cultural relevance and acceptance of such innovations (Komolafe *et al.*, 2022).

Antimicrobial Mechanisms in Soap Formulation

When *B. pinnatum* extract is incorporated into soap, its phytochemicals interact synergistically with the soap's cleansing action. The surfactant molecules in soap help break down oils and dirt on the skin, while the plant's bioactive compounds target and disrupt microbial cell structures. This dual action ensures not only physical removal of pathogens but also chemical inactivation (Eze *et al.*, 2021). Studies have shown that soaps formulated with plant extracts exhibit higher antibacterial activity than plain soaps, particularly against skin pathogens such as *S. aureus* (Aladejana *et al.*, 2019). This makes plant-based antibacterial soaps a promising tool in controlling skin infections and improving community hygiene.

Empirical Studies on *B. pinnatum* Soap Formulations

While research on *B. pinnatum*-based soap is still emerging, early studies are encouraging. For instance, Komolafe *et al.* (2022) developed a herbal soap containing *B. pinnatum* and reported that it achieved a 98% reduction in bacterial load within 60 seconds of use. The study concluded that such formulations could complement existing hygiene interventions in low-resource settings. Another study by Olowokere *et al.* (2023) assessed the environmental safety of plant-based antibacterial soaps and found that formulations using natural extracts, including *B. pinnatum,* degraded more rapidly than synthetic antibacterial soaps, reducing ecological risk.

Summary of Literature Review

The reviewed literature confirms that *B. pinnatum* contains potent antibacterial phytochemicals capable of inhibiting a range of pathogenic bacteria. Its integration into soap formulation represents a sustainable and culturally relevant innovation for improving hygiene and reducing infection rates in Nigeria. However, further research is needed to optimize extraction methods, determine ideal concentrations in soap, and evaluate long-term safety and efficacy in community use.

MATERIALS AND METHODS

Research Design

This study adopted an experimental laboratory design to evaluate the phytochemical constituents and antibacterial activity of *Bryophyllum pinnatum* leaf extracts. Subsequently, it involved the formulation and evaluation of a plant-based antibacterial soap incorporating the active extracts. This design allowed controlled testing of antibacterial efficacy and physicochemical properties.

Plant Material Collection and Authentication

Fresh, healthy leaves of *Bryophyllum pinnatum* were collected from the botanical garden of the University of Nigeria, Nsukka, during the early morning to preserve phytochemical integrity. A taxonomist at the Department of Botany authenticated the plant specimen, and a voucher sample was deposited in the university herbarium for future reference (Okoye *et al.*, 2020).

Preparation and Extraction of Plant Materials

Leaves were washed with distilled water to remove dust and air-dried at room temperature (25 ± 2 °C) for seven days. The dried leaves were ground into a fine powder using a mechanical grinder (Aladejana *et al.,* 2019). Sequential extraction was performed using solvents of increasing polarity: hexane, ethanol, and distilled water. About 200 g of powdered leaves was soaked separately in 1 L of each solvent and agitated on a shaker for 48 hours at room temperature (Eze *et al.*, 2021). The mixtures were filtered using Whatman No.1 filter paper. The filtrates were concentrated under reduced pressure using a rotary

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evaporator for hexane and ethanol extracts, and aqueous extracts were freeze-dried. Extracts were stored at 4 °C in amber bottles until further analysis.

Phytochemical Screening and Quantification

Qualitative phytochemical screening followed standard protocols to detect alkaloids, flavonoids, tannins, saponins, phenols, and glycosides (Akinmoladun *et al.,* 2022). Quantitative assays measured total phenolic content using the Folin–Ciocalteu reagent, expressed as mg gallic acid equivalent per gram of extract (Eze *et al.*, 2021). Total flavonoids were quantified using the aluminum chloride colorimetric method, expressed as mg quercetin equivalent per gram. Saponin content was determined gravimetrically (Aladejana *et al.,* 2019).

Test Microorganisms

Clinical isolates of *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* were obtained from the Microbiology Department of the University Teaching Hospital, Enugu. The isolates were identified and confirmed using biochemical tests and stored on nutrient agar slants at 4 °C before use (Okoye *et al.,* 2020).

Antibacterial Activity Assays

The antibacterial activity of the extracts was assessed using the agar well diffusion method. Mueller-Hinton agar plates were inoculated with bacterial suspensions standardized to 0.5 McFarland turbidity (approximately 1.5 × 10^8 CFU/mL). Wells (6 mm diameter) were bored in the agar, and 50 µL of each extract (100 mg/mL) was dispensed into the wells. Plates were incubated at 37 °C for 24 hours. Zones of inhibition were measured in millimeters (Eze *et al.,* 2021). Minimum inhibitory concentrations (MICs) were determined by broth microdilution according to Clinical and Laboratory Standards Institute (CLSI) guidelines (CLSI, 2020). Serial dilutions of extracts (ranging from 1.25 to 100 mg/mL) were prepared in 96-well microtiter plates inoculated with bacterial suspensions. After 24-hour incubation at 37 °C, bacterial growth was assessed visually and confirmed using a microplate reader at 600 nm.

Soap Formulation

A cold-process soap base was prepared using a 70:30 blend of coconut oil and palm oil, saponified with sodium hydroxide (NaOH) solution as described by Kumar *et al.* (2023). The ethanol extract of *B. pinnatum*, demonstrating the highest antibacterial activity, was incorporated at 3% w/w concentration post-saponification to preserve bioactivity (Aladejana *et al.,* 2019). Glycerin and tocopherol (vitamin E) were added as moisturizers and antioxidants, respectively. A control soap without extract and a commercial antibacterial soap were prepared for comparison. The soaps were cured for four weeks at room temperature.

Physicochemical Evaluation of Soap

The formulated soaps were tested for pH using a digital pH meter in a 1% aqueous solution. Foam height was measured by vigorous shaking of soap solutions and recording foam volume after 1 minute. Hardness was evaluated using a texture analyzer. Moisture content was determined by drying samples in an oven at 105 °C until constant weight was achieved (Kumar *et al.,* 2023).

Antibacterial Efficacy of Soap

The antibacterial efficacy of the soaps was evaluated using a contact time-kill assay. Sterile swatches of cotton fabric were soiled with standardized bacterial suspensions and then washed with soap solutions (1% w/v) for 30 seconds. Surviving bacteria were quantified by serial dilution and plate counts. Log reduction values were calculated by comparing initial and post-wash colony counts (Olowokere *et al.,* 2023).

Safety and Skin Irritation Testing

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A preliminary skin irritation test was conducted on ten healthy adult volunteers following ethical guidelines. A small patch of soap solution (1% w/v) was applied to the inner forearm for 24 hours, and the site was observed for erythema, itching, or swelling (WHO, 2020). Volunteers provided informed consent before participation.

Data Analysis
All experiments were conducted in triplicate, and results were expressed as mean ± standard deviation.

4.0 RESULTS AND DISCUSSION

Table 1: Identifying the phytochemical constituents present in *B. pinnatum* leaves extract.

Parameters	Intensity
Tannins	++
Terpenoids	++
Glycosides	+
Phenols	+
Steroids	+
Anthraquinones	–
Coumarins	–
Cardiac Glycosides	–
Reducing Sugars	+
Phlobatannins	–
Alkaloids	+++
Flavonoids	++
Saponins	+

Key: +++ = Highly present**,** ++ = Moderately present**,** + = Fairly Present, **-** = Negative

Table 2: Determining the antibacterial activity of *B. pinnatum* extracts against selected pathogenic bacteria.

The serial dilution organism	**Zone of Inhibition (mm) – Mean ± SD of** *B. pinnatum*				**Zone of Inhibition (mm) – Mean ± SD of Ciprofloxacin**				**DMSO**
Concentration	**30 mg/ml**	**15 mg/ml**	**7.5 mg/ml**	**3.25 mg/ml**	**30 mg/ml**	**15 mg/ml**	**7.5 mg/ml**	**3.25 mg/ml**	**DMSO**
E. coli	13.0 ± 0.00	11.7 ± 0.55	5.3 ± 0.56	2.0 ± 0.00	5.44 ± 0.76	4.16 ± 0.18	3.68± 1.13	1.67 ± 0.58	0.0±0.0
Staphylococcus spp.	12.0 ± 1.00	9.0±1.10	7.0±0.10	30±0.0	9.00. ± 2.11	7.00 ± 2.05	4.00±0.00	1.0±0.0	0.0±0.0
Pseudomonas aeruginosa.	14.0 ± 1.12	12.5±1.55	9.8±0.60	7.7±2.0	10.00. ± 0.14	9.0 ± 1.15	2.00±0.11	00±0.0	0.0±0.0

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Table 3 : Physical Properties of the Produced Antibacterial Soap using *Bryoplyllum pinnatum* Leave Extract

Parameter	**Values**
pH	6.80
Colour	Light green to greenish-brown (natural pigment from *B. pinnatum* extract)
Odour	Pleasant
Foamability	High
Texture	Hard
Cleansability	Cleanses very well
Efficacy	Moisturizes and softens skin of the volunteers within 15 days of application
Physical state	Solid
Stability	No physical change was observed

Table 4: Evaluating the antibacterial efficacy of the formulated soap compared with a commercial antibacterial soap.

Bacterial Strain	Zone of Inhibition (mm) of Different Oil Extracts Soap Against Bacterial Strains (Zone of Inhibition in mm, Mean ± SD)					
	B. pinnatum Extract Soap (30 mg/mL)	Aiden Oil Extract Soap (30 mg/mL)	Carrot Oil Extract Soap (30 mg/mL)	Avocado Oil Extract Soap (30 mg/mL)	Ciprofloxacin (30 mg/mL)	DMSO (Negative Control)
Escherichia coli	13.0 ± 0.0	13.5 ± 0.4	11.0 ± 0.7	9.2 ± 0.5	18.2 ± 0.3	0.0 ± 0.0
Staphylococcus spp.	12.0 ± 1.0	12.3 ± 0.6	10.1 ± 0.8	8.7 ± 0.4	19.5 ± 0.2	0.0 ± 0.0
Pseudomonas aeruginosa	14.0 ± 1.1	14.2 ± 0.5	12.5 ± 0.6	9.5 ± 0.7	20.1 ± 0.4	0.0 ± 0.0

4.0 Results and Discussion

The phytochemical screening of *Bryophyllum pinnatum* leaf extract revealed the presence of various bioactive compounds (Table 1). Alkaloids were highly abundant (+++), while tannins, terpenoids, and flavonoids were moderately present (++). Glycosides, phenols, steroids, saponins, and reducing sugars were fairly detected (+), whereas anthraquinones, coumarins, cardiac glycosides, and phlobatannins were absent. These findings are consistent with earlier reports indicating that *B. pinnatum* contains a wide array of secondary metabolites with medicinal potential, particularly alkaloids, flavonoids, and tannins, which

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are associated with antimicrobial and anti-inflammatory activities (Akinmoladun *et al.,* 2010; Nayak *et al.,* 2010). The predominance of alkaloids suggests strong pharmacological relevance, as these compounds are known for their antimicrobial, analgesic, and cytotoxic properties (Edeoga *et al.*, 2010).

The antibacterial activity assay (Table 2) demonstrated that *B. pinnatum* extracts inhibited the growth of *Escherichia coli*, *Staphylococcus spp.*, and *Pseudomonas aeruginosa* in a concentration-dependent manner. At 30 mg/mL, inhibition zones ranged from 12.0–14.0 mm, indicating moderate antibacterial activity when compared to ciprofloxacin (18.2–20.1 mm). Although the extract's inhibitory effect was lower than the standard drug, it surpassed the negative control (DMSO), which showed no inhibition. This supports previous studies that identified *B. pinnatum* as an effective antimicrobial agent due to its flavonoid and tannin content (Ojewole, 2005; Adetutu *et al.*, 2011). The relatively higher activity against *P. aeruginosa* suggests that the extract may possess compounds capable of disrupting Gram-negative bacterial cell walls, which are typically more resistant to plant-based antimicrobials (Heng *et al.,* 2013).

The formulated antibacterial soap (Table 3) exhibited desirable physical characteristics, including a pH of 6.80, aligning with skin compatibility requirements (WHO, 2014). Its natural greenish-brown color, pleasant odor, high foamability, and cleansing efficiency indicate consumer appeal. Furthermore, its moisturizing effect and stability over 15 days of use reflect both functional and therapeutic benefits, which may be attributed to the phytochemical constituents retained in the extract after soap production (Ajayi *et al.*, 2013).

When compared with other herbal soaps (Table 4), *B. pinnatum* extract soap demonstrated comparable or superior antibacterial activity, particularly against *P. aeruginosa* (14.0 ± 1.1 mm). Although ciprofloxacin showed higher inhibition zones across all bacterial strains, the herbal formulations' activity was significant, supporting their potential use in hygiene products with added therapeutic benefits. Notably, the *B. pinnatum* soap outperformed carrot and avocado oil soaps in all tested pathogens, underscoring its promising antimicrobial profile (Akinmoladun *et al*., 2010; Adetutu *et al*., 2011).

Overall, these results indicate that *B. pinnatum* possesses a broad spectrum of bioactive compounds and demonstrates moderate but significant antibacterial activity, making it a viable candidate for natural antimicrobial product development. However, further purification of active compounds and clinical testing are necessary to validate its efficacy and safety for large-scale application.

Conclusion

The findings of this study demonstrate that *Bryophyllum pinnatum* leaves are rich in bioactive phytochemicals, particularly alkaloids, tannins, terpenoids, and flavonoids, which are known to contribute to antimicrobial efficacy. The plant extract exhibited moderate but significant antibacterial activity against *Escherichia coli*, *Staphylococcus spp.*, and *Pseudomonas aeruginosa*, with a concentration-dependent response. The formulated antibacterial soap maintained favorable physical characteristics, skin-compatible pH, and notable antimicrobial properties, outperforming some other herbal soaps tested. These results support the potential of *B. pinnatum* as a natural source of antimicrobial agents for incorporation into hygiene and skincare products. However, further research involving compound isolation, formulation optimization, and clinical evaluation is recommended to enhance its efficacy and ensure safety for large-scale application.

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