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Complementary Antimicrobial Spectra and Low-Dose Enhancement of a Curcuma longa–Plumeria spp. Extract Combination, and Activity Retention in Topical Cream Formulations

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ABSTRACT:

Background: The increasing prevalence of antimicrobial resistance (AMR) has heightened the need for alternative therapies derived from medicinal plants. This study investigated the antimicrobial properties of *Curcuma longa* and *Plumeria* spp. extracts, evaluated their phytochemical composition, and incorporated them into topical cream formulations to assess their potential as herbal antimicrobial products.

Methods: Methanolic extracts of the two plants were prepared separately (cold maceration for turmeric; Soxhlet extraction for frangipani) and combined in a 50:50 ratio. Phytochemical screening was performed to identify bioactive constituents. Antimicrobial activity was evaluated by the agar well diffusion method against *Staphylococcus aureus*, *Streptococcus* spp., *Escherichia coli*, *Pseudomonas aeruginosa*, *Aspergillus* spp. and *Candida albicans*. The extracts were formulated into creams (FT_1–FT_5) and assessed for physical properties (colour, odour, homogeneity, viscosity, ease of removal) and antimicrobial efficacy at concentrations of 3.125–100 mg/mL.

Results: Phytochemical analysis revealed saponins, tannins, flavonoids, steroids and terpenoids in both extracts, with cardiac glycosides present only in frangipani; alkaloids were absent from both. The extracts exhibited broad-spectrum inhibition, with the strongest activity recorded for frangipani against *S. aureus* and *P. aeruginosa* (14.5 mm at 100 mg/mL) and for turmeric against *C. albicans* (12.5 mm at 100 mg/mL). Combined extracts broadened the antimicrobial spectrum, inhibiting all test organisms except *Aspergillus* spp. Cream formulations retained measurable antimicrobial activity; FT_2 showed the best balance of potency (6.5 mm against *E. coli* and *P. aeruginosa* at 12.5 mg/mL) and favourable physical properties (highest viscosity, very good homogeneity, fastest removal). FT_3 showed minimal activity,while FT_4 exhibited selectiveinhibition

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of *Streptococcus* spp.

Conclusion: The 50:50 combination of *C. longa* and *Plumeria* spp. extracts possesses broad-spectrum antimicrobial activity that can be retained in a stable, user-friendly topical cream. FT_2 emerged as the most effective formulation, supporting the potential of this plant combination as a natural alternative to synthetic antimicrobial agents.

1. INTRODUCTION

Skin infections are a prevalent public health concern, commonly caused by bacterial and fungal pathogens that colonise or invade the skin. *Staphylococcus aureus* is implicated in a wide spectrum of superficial and deep infections ranging from folliculitis and impetigo to cellulitis, while fungal pathogens such as *Candida albicans* and dermatophytes cause candidiasis, ringworm and athlete's foot (Taylor & Unakal, 2023). Topical antimicrobial agents remain the cornerstone of management, but prolonged and indiscriminate use of synthetic agents has driven antimicrobial resistance (AMR), hypersensitivity reactions and disruption of the skin microbiome [1]. The emergence of multidrug-resistant organisms such as methicillin-resistant *S. aureus* (MRSA) has further limited the efficacy of conventional therapy, creating an urgent need for effective, safe and sustainable alternatives [1].

Medicinal plants and their bioactive compounds have gained attention as alternatives to synthetic antimicrobials. *Curcuma longa* (turmeric) is recognised for antimicrobial, anti-inflammatory and wound-healing properties attributed largely to curcumin and its derivatives, with experimental studies confirming antibacterial and antibiofilm activity against *S. aureus*, including MRSA, and against *C. albicans* (Tian et al., 2025). *Plumeria* spp., particularly *P. alba* and *P. rubra*, contain essential oils, flavonoids and saponins that inhibit *S. aureus*, *Escherichia coli* and *C. albicans*, while also exhibiting antibiofilm and antioxidant properties [2].

Conventional topical agents such as neomycin, mupirocin, fusidic acid and azoles act through single-target mechanisms; their prolonged use is increasingly associated with resistance, local irritation, hypersensitivity and microbiome disturbance, particularly involving MRSA and azole-resistant *Candida* species [3]. Plant-derived compounds, by contrast, possess multicomponent phytochemistry that confers multi-target antimicrobial action, reducing the likelihood of resistance relative to single-target synthetic drugs, and many medicinal plants additionally offer anti-inflammatory and wound-healing benefits relevant to infected, damaged skin [4].

Curcuma longa L. (family Zingiberaceae) rhizomes are rich in curcuminoids (curcumin, demethoxycurcumin, bisdemethoxycurcumin) and essential oils such as turmerone, germacrone and zingiberene (Tian et al., 2025). Curcumin exhibits potent antibacterial activity against Gram-positive organisms, including MRSA, through cell wall disruption, enzyme inhibition and biofilm suppression, and antifungal activity against *C. albicans* and dermatophytes via inhibition of hyphal development and ergosterol synthesis (Tian et al., 2025). Beyond its antimicrobial effects, curcumin downregulates pro-inflammatory mediators such as TNF-α, IL-6 and NF-κB and enhances fibroblast proliferation and collagen deposition, accelerating wound repair [5].

Plumeria spp. (family Apocynaceae), commonly known as frangipani, are used ethnomedicinally for skin diseases, ulcers and infections. Phytochemical studies have identified alkaloids, flavonoids, phenols, tannins, saponins, glycosides and essential oils associated with antimicrobial and anti-inflammatory activity [6]. Essential oils of *P. alba* contain linalool, benzyl salicylate and geraniol, which disrupt microbial membranes, while phenolic and flavonoid constituents confer antioxidant activity that may mitigate oxidative stress at infection sites [7]. Essential oils of *P. alba* have shown significant inhibitory activity against *S. aureus*, *E. coli* and *C. albicans*, together with antibiofilm properties [8], while ethanolic flower extracts of *P. alba* are effective against oral and periodontal pathogens with low cytotoxicity [9] and have further shown inhibitory effects on oral and cutaneous pathogens with minimal cytotoxicity, supporting suitability for dermal application [10].

Combining these two botanicals is pharmacologically rational: *C. longa* primarily targets Gram-positive bacteria, including MRSA, through biofilm disruption and cell wall inhibition [11], whereas *Plumeria* spp. complements this by inhibiting both Gram-positive and Gram-negative organisms (Tian et al., 2025), potentially broadening coverage against polymicrobial skin infections. Both plants inhibit *C. albicans* via distinct mechanisms — turmeric by interfering with ergosterol synthesis and frangipani essential oils by disrupting fungal membranes — which may enhance overall fungistatic/fungicidal potential [12],

while leveraging multiple phytochemical targets is expected to lower the likelihood of resistance development compared with single-molecule synthetic creams [13]. A formulation combining these properties is likely to address polymicrobial infections, support tissue recovery and reduce reliance on conventional synthetic antimicrobials, mitigating both the side effects and resistance pressure associated with current topical therapies [14].

This multi-target rationale is supported by the phytochemical multi-target theory, which holds that herbal extracts containing diverse bioactive compounds (curcuminoids, flavonoids, alkaloids, saponins, phenols, essential oils) exert antimicrobial effects through multiple simultaneous mechanisms, thereby reducing the probability of resistance emergence relative to single-target synthetic drugs [15]. The synergistic herbal formulation concept further proposes that combining plants with complementary pharmacological actions enhances therapeutic efficacy, with *C. longa* contributing antibacterial, antifungal, anti-inflammatory and wound-healing activity and *Plumeria* spp. contributing broad-spectrum antimicrobial, antioxidant and epithelial-regenerative effects [4], together addressing the therapeutic triad of pathogen clearance, inflammation control and tissue repair required for effective skin-infection management [16].

Skin, the largest organ, is the first line of defence against pathogens; bacterial and fungal skin infections are among the commonest dermatological conditions worldwide, ranging from mild superficial lesions to severe complications [17]. Polymicrobial infections involving both bacteria and fungi are common, particularly in immunocompromised individuals and crowded, unhygienic settings, complicating treatment and often necessitating broad-spectrum or combination therapy [18]. Long-term reliance on single-molecule topical agents facilitates resistance through biofilm formation, efflux pump activation and enzymatic drug degradation, prompting a shift toward multi-targeted, plant-based alternatives [19]. Unlike conventional single-molecule drugs, herbal agents such as alkaloids, flavonoids, saponins, phenolics and essential oils act synergistically to disrupt microbial cell walls, interfere with enzymatic processes and inhibit biofilm formation, while additionally offering anti-inflammatory, antioxidant and wound-healing benefits that improve biocompatibility and patient adherence [20]. Studies on *C. longa* and *P. alba* have demonstrated antibiofilm effects against *S. aureus*, *C. albicans* and *Tinea* spp. [21], supporting integration of these botanicals into topical formulations for polymicrobial skin infections.

Several prior studies support the individual and combined antimicrobial potential of these plants. *C. longa* rhizome extracts have shown significant antibacterial activity against *S. aureus*, with clinical isolates more susceptible than standard strains and scanning electron microscopy confirming membrane disruption and cytoplasmic leakage [22]; ethanolic extracts have also inhibited a range of fungal strains [23]; and turmeric essential oil has shown strong activity against both Gram-positive and Gram-negative bacteria, including *S. aureus*, *S. epidermidis*, *E. coli*, *P. aeruginosa* and *Salmonella typhimurium* [21], with further studies confirming significant antibacterial and antifungal effects of turmeric extracts more broadly [24] and of turmeric rhizome extract against multiple bacterial strains, particularly *S. aureus* [25]. A herbal ointment combining *Aloe vera*, *Azadirachta indica* and *C. longa* showed significant inhibitory effects against a range of bacterial and fungal pathogens, supporting the value of combining plant extracts to enhance antimicrobial efficacy [26].

Despite this body of evidence, few studies have combined *C. longa* and *Plumeria* spp. extracts in a single topical cream and systematically evaluated both antimicrobial efficacy and physicochemical formulation performance. This study therefore aimed to evaluate the antimicrobial and antifungal properties of *C. longa* and *Plumeria* spp. extracts, individually and in a 50:50 combination, and to assess their performance after incorporation into topical cream formulations, in order to appraise their potential as natural alternatives for antimicrobial therapy. Specific objectives were to: (i) extract and screen the plants for bioactive phytochemical constituents; (ii) determine the antimicrobial activity of the crude extracts against selected bacterial and fungal pathogens; (iii) incorporate the extracts into stable topical cream formulations; (iv) evaluate the physical properties of the creams; and (v) evaluate and compare the antimicrobial and antifungal efficacy of the crude extracts and the cream formulations.

2. MATERIALS AND METHODS

2.1 Plant material and extraction

Fresh turmeric (*C. longa*) rhizomes and *Plumeria* spp. leaves were obtained from Abraka, Delta State, Nigeria, cleaned, and shade-dried at ambient temperature for three weeks to preserve heat-sensitive phytoconstituents. The dried materials were milled separately into fine powder, yielding 516 g of turmeric powder and 300 g of leaf powder, and stored in airtight containers.

Turmeric powder (516 g) was extracted by cold maceration in 80% methanol for 72 h at room temperature with periodic agitation, protected from light. The mixture was filtered (muslin cloth, then Whatman No. 1 filter paper), the residue re-macerated to ensure exhaustive extraction, and the pooled filtrate concentrated on a water bath at 60 °C to a semi-solid paste, which was stored at 4 °C.

Plumeria spp. powder was extracted by Soxhlet apparatus using 80% v/v methanol until exhaustive extraction (indicated by loss of solvent coloration on siphoning). The filtrate was concentrated on a water bath at 60 °C to a sticky, semi-solid mass and stored at 4 °C.

A combined extract was prepared by mixing the two crude extracts in a 1:1 (w/w) ratio, homogenised, and stored under refrigeration until use.

2.2 Test organisms

Clinical isolates of *Streptococcus* spp., *Staphylococcus* spp. (Gram-positive), *E. coli* and *P. aeruginosa* (Gram-negative), and *C. albicans* and *Aspergillus* spp. (fungal) were obtained from the Microbiology Laboratory, Department of Pathology, Delta State University Teaching Hospital (DELSUTH), Oghara, Nigeria. Identity was confirmed at the Pharmaceutical Microbiology Laboratory, Faculty of Pharmacy, Delta State University, Abraka, using standard procedures (Liu, 2016), comprising Gram staining, colonial morphology, sugar fermentation (dextrose, glucose, lactose, sucrose), indole, motility, hydrogen sulphide, coagulase and catalase tests. Bacterial isolates were maintained on nutrient agar slants and fungal isolates on Sabouraud dextrose agar (SDA) slants at 4 °C, and revived by periodic subculture.

2.3 Phytochemical screening

Standard qualitative phytochemical screening was performed on both extracts to detect alkaloids, flavonoids, tannins, saponins, terpenoids, steroids and cardiac glycosides.

2.4 Antimicrobial susceptibility testing (agar well diffusion)

Mueller–Hinton agar (MHA) was used for bacterial susceptibility testing and SDA for fungal testing, prepared according to manufacturer instructions and sterilised by autoclaving (121 °C, 15 min). Bacterial suspensions were standardised to 0.5 McFarland turbidity ($\approx 1 \times 10^8$ CFU/mL); fungal suspensions were prepared to comparable density. Inoculated plates were prepared by lawn culture, and wells (~6 mm diameter) were aseptically bored and filled with 0.4 g of the respective extract (turmeric, frangipani, or combined) at concentrations of 100, 50, 25, 12.5, 6.25 and 3.125 mg/mL. Methanol served as the negative control and a standard antimicrobial agent as the positive control. Bacterial plates were incubated at 37 °C for 24 h and fungal plates at 28 °C for 72 h. Zones of inhibition (mm) were measured in replicate and mean values recorded. Minimum inhibitory concentrations (MIC) were determined as the lowest concentration producing a measurable zone of inhibition.

2.5 Cream formulation

Creams were prepared as adopted by Okafor et al. (2008). For the aqueous phase, Tween 80, glycerin, methylparaben and propylparaben were combined with the extract dissolved in distilled water and stirred at 70 °C on a magnetic stirrer/hot plate. For the oil phase, cetostearyl alcohol was melted at 70 °C in a water bath, and liquid paraffin and Span 80 were added and mixed. The oil phase was gradually incorporated into the aqueous phase with continuous stirring at 70 °C for 5 min and cooled with stirring to form the cream, which was stored in a cool place. Five formulations (FT_1–FT_5) plus a control (no extract) were prepared according to the quantities in Table 1.

Table 1. Cream formulation composition

Ingredient	FT_1	FT_2	FT_3	FT_4	FT_5	Control
Extract (g)	1	1	1	1	0	–
Paraffin oil (mL)	5.83	5.83	5.83	5.83	5.83	0.996
Span 80 (mL)	3.775	3.775	2.5	2.5	3.775	0.996
Tween 80 (mL)	1.15	1.15	2.325	2.325	1.15	0.177
Cetostearyl alcohol (g)	1.825	1.825	1.825	1.825	1.825	0.925
Methylparaben (g)	0.1	0.1	0.1	0.1	0.1	0.1
Propylparaben (g)	0.025	0.025	0.025	0.025	0.025	0.025
Glycerin (mL)	4	4	4	4	4	1
Distilled water (mL)	9.80	9.80	9.80	9.80	9.80	1.26

2.6 Evaluation of cream formulations

The creams were evaluated for colour, odour, taste, homogeneity, ease of removal, and viscosity (rotational viscometer at 6, 12, 30 and 60 rpm). Antimicrobial activity of each cream was assessed by the agar well diffusion method as described in Section 2.4, using ampicillin as comparator, at concentrations of 3.125–100 mg/mL against the same panel of organisms.

2.7 Data analysis

Data were entered and analysed descriptively using Microsoft Excel®; results are presented as means with corresponding tables and figures.

3. RESULTS

3.1 Phytochemical screening

Frangipani extract tested positive for saponins, tannins, flavonoids, steroids, terpenoids and cardiac glycosides, and negative for alkaloids (Table 2). Turmeric extract tested positive for saponins, tannins, flavonoids, steroids and terpenoids, but negative for alkaloids and cardiac glycosides (Table 2). Both extracts therefore shared saponins, tannins, flavonoids, steroids and terpenoids, differing only in cardiac glycoside content, which was detected exclusively in frangipani.

Table 2. Phytochemical constituents of frangipani and turmeric extracts

Phytochemical	Frangipani	Turmeric
Saponin	+	+
Tannins	+	+
Flavonoids	+	+
Alkaloids	–	–
Steroids	+	+
Terpenoids	+	+
Cardiac glycoside	+	–

3.2 Antimicrobial activity of crude extracts

Frangipani extract showed antimicrobial activity against *S. aureus*, *Streptococcus* spp., *E. coli*, *P. aeruginosa* and *Aspergillus* spp., with the largest inhibition zones (14.5 mm) recorded against *S. aureus* and *P. aeruginosa* at 100 mg/mL; no activity was observed against *C. albicans* at any concentration tested (Table 3). The MIC of frangipani extract was 12.5 mg/mL for *S. aureus*, *P. aeruginosa*, *Aspergillus* spp. and *Streptococcus* spp., and 25 mg/mL for *E. coli* (Table 4).

Turmeric extract inhibited *S. aureus*, *Streptococcus* spp., *E. coli* and *C. albicans*, with the largest zone (12.5 mm) against *C. albicans* at 100 mg/mL, but showed no activity against *P. aeruginosa* or *Aspergillus* spp. (Table 5). The MIC of turmeric extract was 25 mg/mL for *S. aureus*, 12.5 mg/mL for *Streptococcus* spp., and 6.25 mg/mL for *E. coli* (Table 6).

The combined (50:50) extract inhibited *S. aureus*, *Streptococcus* spp., *E. coli*, *P. aeruginosa* and *C. albicans*, with zones up to 12.5 mm, but showed no effect on *Aspergillus* spp. (Table 7). The MIC of the combined extract was 12.5 mg/mL for *S. aureus*, *Streptococcus* spp. and *P. aeruginosa*, and 6.25 mg/mL for *E. coli* (Table 8), indicating a broader antimicrobial spectrum than either single extract.

Table 3. Zone of inhibition (mm) of frangipani extract

Concentration (mg/mL)	*S. aureus*	*Streptococcus* spp.	*E. coli*	*P. aeruginosa*	*Aspergillus* spp.	*C. albicans*
100	14.5	10.5	10	14.5	13	0
50	10	8.5	8.5	11	10	0
25	7	6.5	7	8.5	7	0
12.5	3	5	5.5	6.5	6	0
6.25	0	4	4.5	2	6.5	0
3.125	0	3	4	2	5.5	0
Control	38	14.75	17.5	24	13	–

Table 4. Minimum inhibitory concentration of frangipani extract

Organism	100	50	25	12.5	6.25	3.125 (mg/mL)
S. aureus	–	–	–	–	+	+
Streptococcus spp.	–	–	–	+	+	+
E. coli	–	–	+	+	+	+
P. aeruginosa	–	–	–	+	+	+
Aspergillus spp.	–	–	–	+	+	+

Table 5. Zone of inhibition (mm) of turmeric extract

Concentration (mg/mL)	*S. aureus*	*Streptococcus* spp.	*E. coli*	*P. aeruginosa*	*C. albicans*	*Aspergillus* spp.
100	10	9.5	9.5	0	12.5	0
50	8.5	7	7.5	0	10.5	0
25	6.5	7	7	0	7.5	0
12.5	4	5	6	0	0	0
6.25	4.5	0	4.5	0	0	0
3.125	3.5	0	3.5	0	0	0
Control	28.5	30.5	19	17.5	–	19

Table 6. Minimum inhibitory concentration of turmeric extract

Organism	100	50	25	12.5	6.25	3.125	1.5625 (mg/mL)
S. aureus	–	–	+	+	+	+	+
Streptococcus spp.	–	–	–	+	+	+	+
E. coli	–	–	–	–	+	+	+

Table 7. Zone of inhibition (mm) of combined (frangipani + turmeric) extract

Concentration (mg/mL)	*S. aureus*	*Streptococcus* spp.	*E. coli*	*P. aeruginosa*	*C. albicans*	*Aspergillus* spp.
100	12.5	12.5	9	5.5	11	0
50	10.5	10.5	8.5	5	8	0
25	9	11	7.5	4	6	0
12.5	8	8.5	6	4	0	0
6.25	7	7.5	6.5	3	0	0
3.125	5.5	7	5	2.5	0	0

Table 8. Minimum inhibitory concentration of combined extract

Organism	100	50	25	12.5	6.25	3.125	1.5625 (mg/mL)
S. aureus	–	–	–	+	+	+	+
Streptococcus spp.	–	–	–	+	+	+	+
P. aeruginosa	–	–	–	+	+	+	+
E. coli	–	–	–	–	+	+	+

3.3 Cream formulation characteristics

The creams varied in physical appearance: FT_1 and FT_3 were dark green, FT_2 was creamy green, FT_4 was bright yellow-green, and FT_5 (control) was white (Table 9). All extract-containing formulations had a characteristic or neutral odour and an astringent taste, whereas FT_5 was bland in both odour and taste.

Table 9. Formulation characteristics of the creams

Formulation	Colour	Odour	Taste
FT_1	Dark green	Neutral	Astringent
FT_2	Creamy green	Characteristic	Astringent
FT_3	Dark green	Characteristic	Astringent
FT_4	Bright yellow-green	Characteristic	Astringent
FT_5	White	Bland	Bland

Homogeneity was very good for FT_2, FT_3 and FT_4, good for FT_1, and poor for FT_5 (Table 10). FT_2 had the shortest removal time (6 s), followed by FT_4 (8 s), while FT_1 and FT_3 required longer times (18–19 s); FT_5 was removed quickly (4 s) despite poor homogeneity.

Table 10. Homogeneity and ease of removal of the creams

Formulation	Homogeneity	Ease of removal (s)	Remark
FT_1	Good	19	Good
FT_2	Very good	6	Very good
FT_3	Very good	18	Good
FT_4	Very good	8	Very good
FT_5	Poor	4	Very good

Viscosity was highest for FT_2 across spindle speeds, particularly at 6 rpm, indicating the thickest consistency; FT_1 and FT_4 showed moderate viscosity, FT_3 was comparatively less viscous, and FT_5 (control) had the lowest viscosity at all speeds (Table 11).

Table 11. Viscosity of the creams (cP) at varying spindle speeds

Formulation	6 rpm	12 rpm	30 rpm	60 rpm
FT_1	1675	1900	>1000	>500
FT_2	2175	1400	895	497.5
FT_3	1325	825	550	440
FT_4	1725	1050	640	480
FT_5	125	112.5	105	85

3.4 Antimicrobial activity of the cream formulations

FT_1 showed moderate antimicrobial activity against all organisms tested, with zones of 3–9 mm; the strongest activity was against *P. aeruginosa* and *C. albicans* (9 mm each) at 100 mg/mL, while ampicillin showed negligible activity (Table 12).

FT_2 showed the broadest activity, with zones of 3–8 mm; *P. aeruginosa* and *E. coli* were most sensitive at 12.5 mg/mL (6.5 mm each), and the formulation retained moderate activity against *S. aureus*, *Streptococcus* spp. and *C. albicans* across concentrations, outperforming ampicillin in several instances (Table 13).

FT_3 had weak activity, limited mainly to *S. aureus* (6 mm at 100 mg/mL) and *C. albicans* (5 mm at 100 mg/mL), with no activity against *Streptococcus* spp., *P. aeruginosa* or *E. coli* at any concentration (Table 14).

FT_4 showed moderate, selective activity (3–6.5 mm), with the strongest inhibition against *Streptococcus* spp. (6.5 mm at 100 mg/mL), but no activity against *E. coli* or *C. albicans* at any concentration tested (Table 15).

Table 12. Zone of inhibition (mm) of FT_1

Concentration (mg/mL)	*S. aureus*	*Streptococcus* spp.	*P. aeruginosa*	*E. coli*	*C. albicans*	Ampicillin
100	8	6	9	6	9	0
50	6	4	6	6	8	0
25	4	5	5.5	6	6	0
12.5	0	3	4	4	5	0
6.25	0	3	3	3	0	0
3.125	0	3	3	3	0	1

Table 13. Zone of inhibition (mm) of FT_2

Concentration (mg/mL)	*S. aureus*	*Streptococcus* spp.	*P. aeruginosa*	*E. coli*	*C. albicans*	Ampicillin
100	8	6	3	7	7	5
50	6	5	5	5	6	4
25	6	4	6	6	6	4
12.5	6	3	6.5	6.5	0	0
6.25	0	3	5.5	5	0	0
3.125	0	3	3	3	0	0

Table 14. Zone of inhibition (mm) of FT_3

Concentration (mg/mL)	*S. aureus*	*Streptococcus* spp.	*P. aeruginosa*	*E. coli*	*C. albicans*	Ampicillin
100	6	0	0	0	5	6
50	5	0	0	0	4	4
25	4	0	0	0	0	4
12.5	4	0	0	0	0	0
6.25	3.5	0	0	0	0	0
3.125	3	0	0	0	0	0

Table 15. Zone of inhibition (mm) of FT_4

Concentration (mg/mL)	*S. aureus*	*Streptococcus* spp.	*P. aeruginosa*	*E. coli*	*C. albicans*	Ampicillin
100	6	6.5	4.5	0	0	0
50	3	5	3	0	0	0
25	3	4.5	5	0	0	0
12.5	0	5	4	0	0	0
6.25	0	4	3.5	0	0	0
3.125	0	3	3	0	0	0

Overall, a concentration-dependent trend was evident, with higher extract and cream concentrations producing larger inhibition zones, most consistently for *P. aeruginosa* and *E. coli*. Formulation into cream reduced the extracts' inhibitory activity relative to the crude extracts — for example, frangipani's 14.5 mm zone against *S. aureus* fell to 8 mm in FT_1 — consistent with dilution and possible binding of phytochemicals to cream excipients (Strompfová et al., 2024); nonetheless, FT_2 retained potency comparable to, or exceeding, that of some crude-extract effects.

4. DISCUSSION

Phytochemical screening showed that both extracts were rich in saponins, tannins, flavonoids, steroids and terpenoids, with alkaloids absent from both and cardiac glycosides detected only in frangipani, which may confer it additional antimicrobial character. The observed antimicrobial effects are consistent with the known bioactivity of these constituents: flavonoids disrupt microbial membranes and inhibit nucleic acid synthesis, tannins precipitate microbial proteins, saponins enhance membrane permeability and facilitate extract penetration, and terpenoids exert antifungal activity, together explaining the activity recorded against *S. aureus*, *P. aeruginosa* and the moderate inhibition of *C. albicans*. The absence of alkaloids, which are typically potent antimicrobial agents, may explain why inhibition zones did not exceed 15 mm [27].

Frangipani extract showed strong activity against *S. aureus* and *P. aeruginosa* but no activity against *C. albicans*, whereas turmeric showed the converse pattern, with strongest activity against *C. albicans* and negligible effect on *P. aeruginosa*. MIC values corroborated these patterns: frangipani inhibited *S. aureus*, *P. aeruginosa* and *Streptococcus* spp. at 12.5 mg/mL but required 25 mg/mL for *E. coli*, while turmeric was most potent against *E. coli* (6.25 mg/mL) but required higher concentrations (25 mg/mL) for *S. aureus*. This organism-specific, concentration-dependent pattern suggests that turmeric phytochemicals may act preferentially on Gram-negative bacteria, whereas frangipani's broad-spectrum effect becomes apparent mainly at higher doses. These findings align with previous reports of frangipani activity against *S. aureus* and *Pseudomonas* spp. (Sinaga & Jaya, 2022) and of turmeric's curcumin-associated antifungal and anti-inflammatory activity [25], although they diverge from reports of turmeric sensitivity in *P. aeruginosa*, possibly reflecting differences in phytochemical concentration or extraction methodology [28].

Combining the extracts broadened the antimicrobial spectrum to include *S. aureus*, *Streptococcus* spp., *E. coli*, *P. aeruginosa* and *C. albicans*, although *Aspergillus* spp. remained resistant and potency against individual organisms was not consistently enhanced beyond that of the single extracts (peak zones of 12.5 mm for *S. aureus* and *Streptococcus* spp.). This indicates that the

combination principally improves spectrum coverage rather than potency, possibly reflecting interactions between the combined phytochemical constituents.

Incorporation of the extracts into cream bases (FT_1–FT_5) preserved measurable antimicrobial activity while also shaping the physical characteristics of the formulations. FT_2 and FT_4 combined the most favourable texture with retained antimicrobial performance; the control cream (FT_5), lacking active extract, was poorly homogenised, had low viscosity and no antimicrobial activity, confirming that the extracts were the principal contributors to efficacy. FT_1 retained the strongest effect on Gram-negative bacteria, notably *P. aeruginosa* (9 mm), while FT_2 showed the most balanced activity across the pathogen panel, particularly against *P. aeruginosa* and *E. coli* (6.5 mm at 12.5 mg/mL), consistent with a synergistic effect from the combined extracts that reduced variability in pathogen sensitivity. FT_3 was comparatively weak, limited to slight inhibition of *S. aureus* and *C. albicans*, suggesting lower potency or stability of this batch in cream form, whereas FT_4 displayed narrow but potent activity against *Streptococcus* spp. (6.5 mm), a pattern that could be exploited for targeted therapeutic use. Across formulations, higher concentrations produced larger inhibition zones, an effect more pronounced for *P. aeruginosa* and *E. coli* than for *Streptococcus* spp. and *C. albicans*, mirroring the concentration-dependence observed for the crude extracts and indicating that antimicrobial efficacy remained dose-responsive despite formulation.

Comparison of crude-extract and cream inhibition zones showed an expected reduction in potency after formulation — for example, frangipani's 14.5 mm zone against *S. aureus* fell to 8 mm in FT_1 — attributable to dilution and possible binding of phytochemicals to cream excipients, with correspondingly higher MIC values for the creams reflecting reduced bioavailability of active compounds in topical bases (Strompfová et al., 2024). Nevertheless, this reduction was partly offset by the sustained-delivery potential of the cream matrix, and FT_2 maintained antimicrobial activity comparable to, or exceeding, some crude-extract effects, indicating an optimised balance of emulsifier and extract ratios in this formulation.

5. CONCLUSION

The 50:50 combination of *C. longa* and *Plumeria* spp. methanolic extracts possessed broad-spectrum antimicrobial and antifungal activity attributable to a shared profile of saponins, tannins, flavonoids, steroids and terpenoids, complemented by cardiac glycosides unique to frangipani. Formulation into topical creams (FT_1–FT_4) preserved measurable antimicrobial activity alongside acceptable physicochemical characteristics, with FT_2 emerging as the most effective formulation, combining strong antimicrobial potency with very good spreadability, favourable viscosity and rapid ease of removal. FT_4 performed well against *Streptococcus* spp. specifically, while the extract-free control (FT_5) confirmed that antimicrobial activity was attributable to the incorporated extracts rather than the base. These findings support the development of plant-based antimicrobial creams as a promising, cost-effective alternative to synthetic agents for the management of skin infections in the context of rising antimicrobial resistance. Further work should address formulation stability under varied storage conditions, expanded antimicrobial screening including multidrug-resistant pathogens, toxicological evaluation, and clinical assessment, alongside exploration of alternative extract ratios and delivery forms (gels, ointments, soaps), to validate and extend the therapeutic potential of this herbal formulation.

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AUTHOR CONTRIBUTIONS

The author conceived and designed the study, performed the laboratory work, analysed the data, and wrote the manuscript.

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CONFLICT OF INTEREST

The author declares no competing interests.

ETHICS STATEMENT

Not applicable (in vitro study using bacterial and fungal isolates; no human or animal subjects were involved).

CONSENT FOR PUBLICATION

Not applicable.

DATA AVAILABILITY STATEMENT

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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