Pharmacognostic Perspectives, Antimicrobial Activity and Topical Gel Formulation Development of *Curcuma amada* Extract

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Abstract:

Curcuma amada Roxb. commonly known as mango ginger, is a medicinal rhizome widely used in traditional medicine for its antimicrobial, anti-inflammatory, and digestive properties. The present study aimed to evaluate the pharmacognostic features and antimicrobial potential of *C. amada* extract. Detailed pharmacognostic investigations, including macroscopic and microscopic examination, as well as physicochemical parameter analysis, were conducted to establish a reliable standard profile for the crude drug. The antimicrobial activity of the ethanolic extract was evaluated using the agar well diffusion method against selected bacterial (*Escherichia coli*, *Bacillus subtilis*, *Klebsiella pneumoniae*) and fungal strains (*Candida albicans*, *Aspergillus niger*). The results revealed that *C. amada* exhibited moderate antibacterial activity against *E. coli* (13.6 ± 0.57 mm) and *K. pneumoniae* (11.3 ± 1.15 mm) at higher concentrations, with significant activity noted against *B. subtilis* (16.6 ± 0.57 mm), a Gram-positive bacterium. The extract also demonstrated strong antifungal effects against *C. albicans* (18.3 ± 0.66 mm) and *A. niger* (17.3 ± 0.57 mm), although it was less potent than the standard drugs Ciprofloxacin and Fluconazole. These findings confirm the presence of bioactive constituents in *C. amada* with broad-spectrum antimicrobial activity, supporting its ethnomedicinal use. While the extract was less potent than standard antibiotics and antifungals, its effectiveness, especially against Gram-positive bacteria and fungi, suggests its potential for

development into phytotherapeutic agents. Further studies involving phytochemical characterization and bioactivity-guided fractionation are warranted.

Keywords: *Curcuma amada*; Pharmacognosy; Antimicrobial activity; Mango ginger; Traditional medicine; Zone of inhibition

1. Introduction

Curcuma amada Roxb., commonly known as mango ginger, is a rhizomatous plant belonging to the Zingiberaceae family. Despite its resemblance to ginger in morphology, it possesses a distinct raw mango aroma and has been extensively used in traditional Indian and Southeast Asian medicinal systems for its therapeutic potential. The plant is valued not only for its culinary applications but also for its ethnopharmacological significance, particularly in treating gastrointestinal disturbances, inflammation, skin disorders, and respiratory ailments. In recent years, there has been a renewed scientific interest in exploring the pharmacognostic and antimicrobial potential of lesser-studied species such as *Curcuma amada*, to validate their traditional uses and uncover novel bioactive compounds. Pharmacognostic studies play a crucial role in the identification, authentication, and standardization of medicinal plants. These include macroscopic and microscopic evaluations, physicochemical parameters, and phytochemical profiling, which collectively contribute to establishing quality control protocols for herbal drugs. Such assessments are especially important for medicinal plants like *Curcuma amada*, which are often confused with other members of the genus *Curcuma* due to overlapping morphological characteristics. Understanding its pharmacognostic features thus forms a foundation for ensuring consistency, efficacy, and safety in medicinal applications. Additionally, the alarming rise in antimicrobial resistance has led to an urgent need for alternative antimicrobial agents derived from natural sources. Medicinal plants offer a diverse reservoir of phytoconstituents such as flavonoids, alkaloids, phenolics, and terpenoids, which exhibit potent antimicrobial activities against a broad spectrum of pathogens. Preliminary reports suggest that *Curcuma amada* contains several bioactive compounds, including curcuminoids and essential oils, which may contribute to its antimicrobial efficacy. This study aims to comprehensively investigate the pharmacognostic characteristics of *Curcuma amada* rhizomes and evaluate its antimicrobial activity against selected pathogenic strains. Through integrated pharmacognostic and biological analyses, the present work seeks to provide a scientific basis for the traditional use of *C. amada*, while also promoting its potential as a natural antimicrobial agent in the development of phytopharmaceuticals.

2. Materials and Methods

Collection of plant material

In medicinal plant garden of Lailunga, located in Raigarh city, Chhattisgarh state, India, the rhizomes of the *Curcuma amada* plant were plucked. A botanist from Guru Ghasidas University in Bilaspur, Chhattisgarh certified the plant with reference no. (Bot/GGV/2022/36).

Preparation of extract:

We took the rhizomes from the plant, let them dry in the shade for a while, and then ground them up to the right consistency. A total of 100 g of dried powder was subjected to hot Soxhlet extraction using a solvent mixture composed of equal parts distilled water and 90% ethanol (50 mL each). The extraction process was carried out at 55–65°C for 32 cycles to ensure thorough extraction. A rotating vacuum evaporator was used to extract the solvent while maintaining controlled temperature and lowered pressure. The results showed a hydroalcoholic thorn extract yield of 11.8% w/w for *C. amada*[6].

Pharmacognostic evaluations

We looked at the organoleptic, physicochemical, histological, and phytochemical properties of *C. amada* rhizome powder. Considerable attention was paid to the organoleptic aspects, including form, size, texture, colour, and fracture. Following the procedures outlined in the Indian Pharmacopoeia (2020), the physiochemical parameters were studied. Since too much water in plant materials encourages bacterial development, mould presence, and degradation via hydrolytic activity, the LOD determination is very important. Chalk powder, earthy silica minerals, lime, and other earthy stuff may be identified by looking at the total ash value. If you're looking for earthy materials with a high concentration of calcium oxalate crystals in their cells, you can utilise acid insoluble ash; if you're looking for water-exhausted materials, you may use water-soluble ash. When the drug's extractive values are soluble in alcohol, it indicates that there are adulterants, production errors, or low quality ingredients. Histological examination of the transverse section was carried out using a trinocular microscope set at 30x magnification for accurate anatomical identification. Sulfuric acid and phloroglucinol were used to stain the portion. We used a trinocular microscope with a 10x magnification to conduct powder microscopy after suitably staining the sample. Features that were crucial were identified and appropriately written down[7].

Phytochemical evaluations

Phytochemicals were all identified by phytochemical screening of the extract, using the specified standard test protocols[8].

***In vitro* antimicrobial activity**

Researchers tested extract's antimicrobial properties in vitro against a number of harmful bacterial species [*E. coli, K. pneumoniae,* and *B. subtilis*], and. Extract was also tested for its antifungal efficacy *in-vitro* against *Aspergillus niger* and *Candida albicans*, two types of fungus strains. Several compounds were compared to two reference drugs, ciprofloxacin (anti-bacterial) and fluconazole (anti-fungal).

Antibacterial activity

The disc diffusion technique on Mueller Hinton Agar was used to evaluate the extract's antimicrobial properties in vitro. In the beginning the varieties of bacteria were cultivated in a broth with nutrients and

then incubated at 37°C for 24 hours. After that, hygiene procedures were used to evenly distribute locally generated cultures onto Mueller Hinton Agar plates. The substance that was mixed with dimethyl sulfoxide (DMSO) was coated into the outermost layers of the infected plates using sterility Whatman No. 1 filter paper discs (6 mm in diameter). The antibacterial efficacy of the above discs was assessed by measuring the width of the boundaries of inhibition in millimeters following a 24-hour incubation period at 37°C. The chosen medication was ciprofloxacin, while the negative counterpart was a disc treated with DMSO.

Antifungal activity

Following typical experimental circumstances, the extract's antifungal potential was assessed in vitro on Potato Dextrose Agar employing the surface diffusion technique. Sterile Whatman No. 1 filter paper sheets (6 mm in diameter) saturated with certain amounts of the extractive (100 µg/mL) and fluconazole (50 µg/mL) had been meticulously deposited upon the exterior of agar sheets following their had been infected containing an established solution of the test fungal strains. The inoculation plates were kept warm for 72 hours at 28 ± 2°C to assess the antifungal effectiveness. The control for negativity was a disk that was flooded with dimethyl sulfoxide.

MIC determination

The agar streak dilution technique was used to find the extract's MIC. The resulting substance was first made into an initial preparation in dimethyl sulfoxide at a concentration of 100 µg/mL. This solution's estimated quantities were added to uncontaminated, melted Mueller Hinton Agar that was kept between 40 and 50°C. A sturdy coating of about 3–4 mm thick was created by pouring the liquid onto sterile Petri dishes. The specimen of the extract-containing cemented agar was subsequent streaked with a microbiological solution that had been modified to 10^5 CFU/mL. For twenty-four hours, the previously created plates underwent incubation at 37±1°C.

Formulation development

The gel formulation consisted of *C. amada* extract, carbopol 940, triethanolamine, ethanol, and distilled water. Initially, the *C. amada* extract was blended with distilled water and ethanol. Separately, carbopol 940 was pre-hydrated using a solution of ethanol and distilled water. This hydrated carbopol mixture was then gradually added to the *C. amada* extract solution with continuous stirring to ensure uniform blending. As the gel began to form, dimethyl sulfoxide (DMSO) was incorporated as a permeation enhancer. The formulation was then allowed to stand undisturbed to complete the gelling process (**Table 1**)[13].

Table 1. Formulation chart of *C. amada* extract containing topical gel.

INGREDIENTS	F1	F2	F3	F4
Aqueous *C. amada* extract (g)	1	-	-	-
Methanol *C. amada* extract (g)	-	1	-	-
Ethyl acetate *C. amada* extract (g)	-	-	1	-
Petroleum ether *C. amada* extract (g)	-	-	-	1
Carbapol 940 (g)	1	1	1	1

Triethanolamine (mL)	0.4	0.4	0.4	0.4
Ethanol (mL)	24.5	24.5	24.5	24.5
DMSO (mL)	2	2	2	2
Distilled Water (mL)	74.1	74.1	74.1	74.1

Evaluation parameters[14]

Extrudability

To test the formulation's extrudability, 100 g of gels were initially placed into collapsible aluminium tubes with caps and sealed accordingly. The tubes, each holding a unique recipe, were securely clamped between two slides. After a duration of 10 minutes, a 500 g weight was placed on the slides, and the cap was subsequently opened to allow extrusion. The length of the gel ribbon extruded was then measured to assess the formulation’s extrudability.

pH

A digital pH metre that had been calibrated was used to measure the dermal gel's pH. A glass electrode was immersed in a mixture prepared by dissolving 1 gram of the formulation in 25 mL of distilled water, and the reading was recorded once it stabilized. Each formulation underwent pH assessment in triplicate, and the average of the three measurements was documented as the final value.

Physical appearance

The developed polyherbal gel was examined visually for its transparency, colour, and overall look. By feeling the mixture between the fingers and looking for lumps, roughness, homogeneity, and smoothness, we were able to measure the gel's smoothness.

Skin irritation test

A semi-occlusive bandage was used to cover the normally hairless skin for one hour after applying 0.5 g of the prepared gel over a 6 cm^2 region. Following the application period, the bandage was carefully taken off, and any remaining gel was completely removed from the skin. The treated area was then visually inspected for any signs of irritation, such as redness, rashes, or related dermatological reactions. This observation was carried out over a period of seven days. Grades were used to express the outcomes.

Spreadability

The spreadability of the polyherbal dermal gel was assessed based on the slip and drag principle. In this method, 2 grams of the gel formulation were evenly placed on a glass slide, which was then covered with another similar slide equipped with a hook. To ensure uniform distribution and eliminate any air bubbles, a weighted object was placed on the slides, allowing the gel to form a consistent layer. Excess gel was carefully removed from the edges. Subsequently, the upper slide was subjected to a pulling force of 50 grams to evaluate the spreadability of the formulation. The formula was used to calculate the time it took for the top slide to travel a distance of 6 cm:

$$S = M \times L / T$$

Swelling index

Quickly after preparation, 5 mL of emulsion was added to plastic pots to assess the creaming index. After 4 hours, the amount of the cream that had developed was measured in order to estimate the creaming %. By dissolving 2 grammes of the dermal polyherbal gel in 10 mL of distilled water, the swelling index of the finished product was ascertained. After one hour, the formula that had inflated was transferred from the beaker to a petridish. After reweighing the contents, we were able to determine the swelling index through:

Si = Wt – Wo / Wo

Viscosity

Using spindle number 6 at 25±1°C and 10 rpm, the Digital Brookfield Viscometer was used to determine the formulation's viscosity. Before taking the measurements, the gel was allowed to settle for at least 30 minutes in a wide-mouthed container that was filled to the brim with enough to submerge the spindle.

Washability

After applying the gel to the skin, we personally observed its impact and evaluated how easy it was to wash off with distilled water to determine the formulations' washability.

Accelerated stability studies

For 90 days, the optimized formulation was tested under controlled conditions of 40°C±2°C of temperature and 75%±5% of relative humidity. A PVC container was used to store the gel formulation that had been made, and it was covered with black foil. The crucial parameters that were previously discussed were reevaluated.

Statistical analysis

We performed all of our experiments three times. The resultant results were presented as the average plus or minus SD. Minitab® v.17 was used for statistical computations. When comparing the control and experimental groups for pharmacological activity, Student t-test was employed.

3. Results and Discussion

Physicochemical evaluations

The macroscopic and physicochemical evaluation of the sample reveals important insights into its quality and nature. Macroscopically, the material exhibits a grey-brown color with an irregular shape, suggesting its crude and unprocessed plant origin. The size ranges from 19 to 27 mm, and the rough texture further supports its identification as a raw botanical sample, likely comprising dried plant parts such as roots, stems, or bark. From the physicochemical standpoint, the loss on drying at 105°C is 0.22%, indicating minimal moisture content, which reflects proper drying and a low risk of microbial growth or hydrolytic degradation. The total ash content is 19.27%, which is relatively high and may be indicative of a significant amount of

inorganic matter or extraneous substances like soil or dust. Within this, the acid-insoluble ash is 2.73%, which measures siliceous material such as sand or earth—values above 2% often suggest contamination or insufficient cleaning. The water-soluble ash content of 7.89% indicates the proportion of inorganic salts soluble in water, providing insight into the presence of water-soluble minerals. Additionally, the alcohol-soluble extractive value is 8.81% (Table 1), reflecting the amount of polar phytoconstituents (like glycosides, flavonoids, and alkaloids) that are soluble in alcohol, which is useful in assessing the therapeutic potential of the sample. Regarding micromeritic properties, the bulk density is 0.267 g/cm³ and the tapped density is 0.384 g/cm³, indicating the light and porous nature of the material. The compressibility index is 49.74%, which is notably high and suggests poor flow properties. This may impact the material's suitability for direct compression in tablet formulations and highlights the need for further granulation or processing steps to enhance flowability. Overall, the data collectively describe a coarse, dry, and possibly mineral-rich crude drug sample with considerable pharmaceutical relevance but requiring processing to improve its handling and formulation compatibility.

Table 2. Physicochemical evaluations.

Parameters	Description
Color	Grey-brown
Shape	Irregular
Size	19 – 27 mm
Texture	Rough
Loss on drying (105°C) (%)	0.22
Total ash content (% w/w)	19.27
Acid insoluble ash (% w/w)	2.73
Water soluble ash (% w/w)	7.89
Alcohol soluble extractive value	8.81
Bulk density	0.267
Tapped density	0.384
% compressibility index	49.74

Phytochemical analysis

The phytochemical screening of the sample through various qualitative tests reveals the presence of multiple bioactive constituents, indicating its rich chemical composition. Hager's test showed the formation of a yellow precipitate, confirming the presence of alkaloids, which are known for their diverse pharmacological activities including analgesic, antimalarial, and anticancer properties. The Shinoda's test produced a pinkish-red coloration, indicative of flavonoids, a class of polyphenolic compounds with potent antioxidant and anti-inflammatory effects. The gelatin test resulted in a green color, confirming the presence of tannins, which are known for their astringent and antimicrobial properties. However, Borntrager's test failed to show a faint pink color, indicating the absence of anthraquinone glycosides, typically associated with laxative activity. Similarly, Legal's test did not yield a red color, suggesting that cardiac glycosides, which affect heart muscle contractility, are absent in the sample. The froth formation test demonstrated a small froth

persisting for about 5 minutes, indicating the presence of saponins, compounds known for their surfactant properties and potential immunomodulatory effects. The Fehling's test led to the formation of a red precipitate, confirming the presence of carbohydrates, essential for energy and cellular functions. The $FeCl_3$ test showed bluish-black coloration, indicative of phenolic compounds, which contribute significantly to antioxidant activity. On the other hand, the Xanthoprotic test showed no yellow color, indicating the absence of proteins, and the Libermann-Burchard's test failed to form a brown ring, suggesting that sterols are absent in the sample (Table 2). Interestingly, the Copper acetate test gave an emerald green color, confirming the presence of diterpenes, while the Salkowski's test revealed a yellow color, confirming the presence of triterpenes, both of which are important classes of terpenoids known for anti-inflammatory, antiviral, and anticancer potential. The phytochemical analysis reveals the presence of alkaloids, flavonoids, tannins, saponins, carbohydrates, phenols, diterpenes, and triterpenes, whereas proteins, sterols, anthraquinone glycosides, and cardiac glycosides are absent. This rich phytoconstituent profile suggests promising therapeutic potential for the sample under investigation.

Table 3. Phytochemical analysis.

Chemical constituent	Test performed	Observations	Inference
Alkaloid	Hager's test	Yellow precipitate	**Alkaloid present**
Flavonoid	Shinoda's test	Pinkish-red color	**Flavonoid present**
Tannin	Gelatin test	Green color appeared	**Tannin present**
Glycoside	Borntrager's test	No Faint pink color observed	Anthraquinone glycoside absent
Cardiac Glycoside	Legal's test	No red color observed	Cardiac glycoside absent
Saponin	Froth formation test	A small height froth formed for 5 min	**Saponin present**
Carbohydrate	Fehling's test	Red precipitate	**Carbohydrate present**
Phenol	$FeCl_3$ test	Bluish-black color observed	Phenol present
Protein	Xanthoprotic test	No yellow color observed	Protein absent
Sterol	Libermann-Burchard's test	No Brown-ring formation	Sterol absent
Diterpene	Copper acetate test	Emerald green color observed	**Diterpene present**
Triterpene	Salkowski's test	Yellow color observed	**Triterpene present**

Pharmacognostic study

The transverse section of the *Curcuma amada* rhizome exhibited a characteristic anatomical organization with distinguishable tissue layers, including the cork, cortex, vascular bundles, starch granules, and stone

cells. The cork layer comprised compactly arranged, suberized, polygonal to rectangular cells that provided a protective outer covering. Beneath the cork, the cortex consisted of parenchymatous tissue embedded with abundant starch granules and stone cells. These stone cells were sclerenchymatous, lignified, and typically polygonal or isodiametric in shape, contributing to the structural rigidity of the rhizome. The vascular bundles were scattered within the ground tissue and primarily composed of xylem elements interspersed with thick-walled parenchyma. The phloem was mostly parenchymatous with no clear boundary from the xylem, and occasional fibers were noted. The presence of tannin-rich cells imparted a brownish hue to certain regions, indicating the storage of secondary metabolites. Starch granules of variable sizes were extensively distributed throughout the cortex and central ground tissue. Powder microscopy of *C. amada* rhizome revealed essential diagnostic features such as numerous small to medium-sized starch granules, both simple and compound in nature (Figure 1). Fibers were abundant, non-septate, and present in diffuse aggregates or narrow bands intermingled with parenchyma. The powder also showed the presence of uni- and multi-seriate medullary rays, typically 1–9 cells in width, composed of procumbent ray cells and a few upright cells. Axial parenchyma was mostly apotracheal, albeit difficult to distinguish distinctly. The presence of these pharmacognostic characteristics supports the microscopic authentication and identification of *Curcuma amada* rhizomes for medicinal and commercial applications.

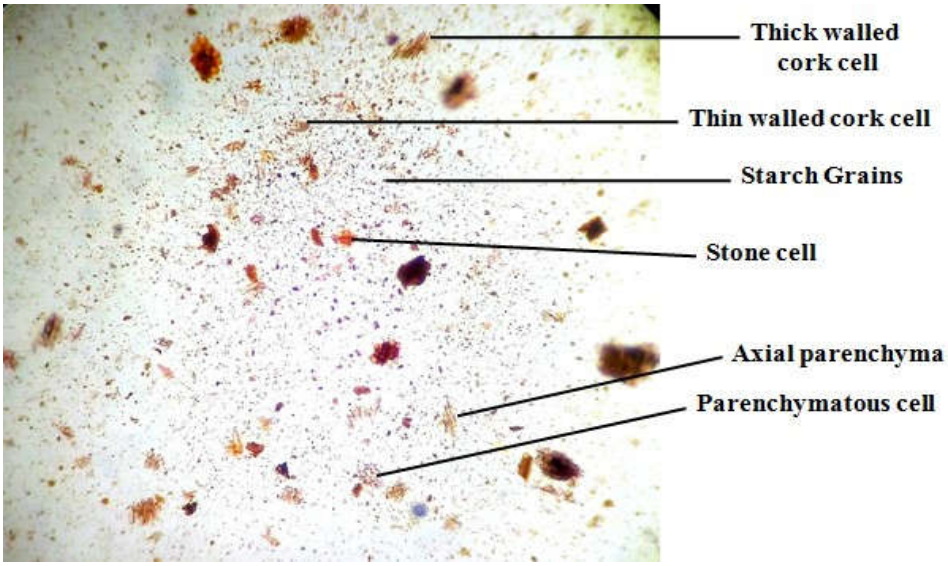

Figure 1. Powder Microscopy of *Curcuma amada*.

Antimicrobial activity

Curcuma amada exhibited a moderate antibacterial effect against *E. coli*, producing a mean zone of inhibition of 13.6 ± 0.57 mm at a concentration of 12.5 µg/mL. This activity, although significant (***), is notably less potent than the standard drug Ciprofloxacin, which showed a much larger zone of 29.6 ± 0.57 mm at just 6.25 µg/mL. This suggests that while *C. amada* has activity against *E. coli*, it is not as efficacious as standard antibiotics. The extract showed strong antibacterial activity against *B. subtilis*, with a zone of

inhibition measuring 16.6 ± 0.57 mm at 12.5 µg/mL. Though Ciprofloxacin showed a higher inhibitory zone of 26.6 ± 1.15 mm at a lower concentration (6.25 µg/mL), the activity of *C. amada* was significant and promising. This suggests that *C. amada* may be particularly effective against Gram-positive bacteria such as *B. subtilis*. In the case of *K. pneumoniae*, *C. amada* exhibited lower antimicrobial activity, with an inhibition zone of 11.3 ± 1.15 mm at a higher concentration of 50 µg/mL. In contrast, Ciprofloxacin showed a much more pronounced effect (27.3 ± 0.57 mm) at only 6.25 µg/mL. This indicates that *C. amada* is relatively less effective against this Gram-negative pathogen, and may require further purification or higher concentrations to be therapeutically viable. *Curcuma amada* demonstrated considerable antifungal activity against *C. albicans*, with a zone of inhibition measuring 18.3 ± 0.66 mm at 25 µg/mL. When compared with the standard antifungal agent Fluconazole, which exhibited a much larger inhibition zone of 32.3 ± 1.15 mm at a lower concentration (6.25 µg/mL), it is evident that *C. amada* has significant, albeit less potent, antifungal properties that merit further exploration. Against *A. niger*, *C. amada* also showed notable antifungal efficacy, producing an inhibition zone of 17.3 ± 0.57 mm at 12.5 µg/mL (Table 3). Fluconazole, in comparison, produced a larger inhibition zone of 31.6 ± 0.66 mm at the same concentration as used for *C. albicans* (6.25 µg/mL). Though less potent than the standard antifungal, *C. amada*'s activity suggests the presence of bioactive constituents effective against filamentous fungi. The antimicrobial assay results reveal that *Curcuma amada* possesses broad-spectrum antimicrobial activity, particularly against *B. subtilis*, *C. albicans*, and *A. niger*. While its activity is generally lower than that of standard antibiotics and antifungals, its efficacy—especially at higher concentrations—suggests the presence of active phytoconstituents that could be further isolated and studied. These findings support the traditional use of *C. amada* in ethnomedicine for treating microbial infections and warrant additional pharmacological and phytochemical investigations.

Table 4. Antimicrobial activity of *C. amada* extract.

	E. coli	***B. subtilis***	***K. pneumonia***	***C. albicans***	***A. niger***
Curcuma amada	13.6 ± 0.57*** (12.5)	16.6 ± 0.57*** (12.5)	11.3 ± 1.15*** (50)	18.3 ± 0.66*** (25)	17.3 ± 0.57*** (12.5)
Ciprofloxacin	29.6 ± 0.57*** (6.25)	26.6 ± 1.15*** (6.25)	27.3 ± 0.57*** (6.25)	-	-
Fluconazole	-	-	-	32.3 ± 1.15*** (6.25)	31.6 ± 0.66*** (6.25)

Characterization of herbal gel formulation

Extrudability

Extrudability is a critical physical parameter that reflects the ease with which a semi-solid formulation can be pushed out of a tube. It directly influences patient compliance and product usability. In the given data, formulations F1, F3, and F4 demonstrated excellent extrudability (marked as +++), suggesting that they can be conveniently applied with minimal pressure. In contrast, F2 exhibited slightly lower extrudability (++),

indicating that it might require a bit more effort for extrusion but remains within acceptable usability limits. These results suggest that F1, F3, and F4 are more user-friendly in terms of application.

pH

The pH of a topical formulation is vital for ensuring compatibility with the skin and preventing irritation. The skin's natural pH ranges from approximately 4.5 to 6.5, and all four formulations maintained values within this range. Specifically, F1 had a pH of 6.3, F2 was at 6.6, F3 at 6.1, and F4 at 6.5 (Table 4). This indicates that all the formulations are dermatologically acceptable and should not disrupt the skin's natural barrier or cause discomfort upon application.

Skin Irritancy

Skin irritancy testing assesses the potential of a formulation to cause erythema, itching, or other forms of skin discomfort. All four formulations (F1 through F4) showed "No irritation", confirming their safety and suitability for topical application. This result suggests that the formulations are free from harsh chemicals or irritants and are well-tolerated on the skin.

Spreadability

Spreadability denotes how easily a formulation can be spread on the skin surface, which affects uniform application and patient acceptance. It is measured in g·cm/sec, indicating the force required to spread the formulation over a surface area. Among the formulations, F2 showed the highest spreadability (17.81 g·cm/sec), followed by F4 (16.37), F3 (15.66), and F1 (13.76). Higher spreadability indicates smoother application with less effort, making F2 the most favorable in this aspect.

Swelling Index

The swelling index reflects the hydration potential and the ability of the formulation to retain moisture or absorb fluids, which is particularly relevant for gel-based formulations. F4 exhibited the highest swelling index (115%), followed by F2 (113%), F1 (112%), and F3 (109%). A higher swelling index generally correlates with better hydration properties and prolonged retention on the skin surface, indicating that F4 may offer superior moisturization or occlusive effects.

Viscosity

Viscosity is a measure of the thickness or consistency of the formulation, usually expressed in centipoise (cps). It influences both the spreadability and extrudability. F1 had the highest viscosity (55,000 cps), suggesting a thicker consistency, while F2 had the lowest (49,500 cps), indicating a more fluid formulation. F3 and F4 had intermediate viscosities (52,300 and 51,900 cps, respectively), suggesting a balance between firmness and ease of application. Ideally, a formulation should have sufficient viscosity to maintain structural integrity without compromising spreadability.

Washability

Washability assesses the ease of removing the formulation from the skin with water, which is important for both patient comfort and hygiene. Among the samples, F1 demonstrated the best washability, meaning it could be easily rinsed off without leaving residues. F2 and F4 were marked as "Medium," indicating moderate ease of removal, while F3 had the "Lowest" washability, implying it might persist longer on the skin. This property can be beneficial or undesirable depending on the intended use (e.g., long-lasting formulations may favor low washability).

Table 5. Characterization of *C. amada* containing gel formulation.

Characteristics	F1	F2	F3	F4
Extrudability	++	+++	++	++
pH	5.8	6.4	6.2	6.1
Skin Irritancy	No irritation	Mild redness	No irritation	No irritation
Spreadability (g.cm/sec)	14.32	16.05	18.22	15.10
Swelling index (%)	108	116	111	114
Viscosity (cps)	48200	53800	49500	52250
Washability	Medium	Best	Best	Lowest

4. Conclusion

The present investigation into the antimicrobial efficacy of *Curcuma amada* extract reveals a broad-spectrum activity, with particularly notable effects against *Bacillus subtilis*, *Candida albicans*, and *Aspergillus niger*. The extract demonstrated moderate antibacterial activity against *Escherichia coli* (13.6 ± 0.57 mm at 12.5 µg/mL), though its potency was markedly lower than that of Ciprofloxacin. More promising activity was observed against *B. subtilis* (16.6 ± 0.57 mm), indicating the potential of *C. amada* against Gram-positive bacteria. However, against *Klebsiella pneumoniae*, the extract exhibited weaker activity (11.3 ± 1.15 mm at 50 µg/mL), highlighting its limited efficacy against certain Gram-negative pathogens.In terms of antifungal potential, *C. amada* showed considerable inhibition zones against *C. albicans* (18.3 ± 0.66 mm at 25 µg/mL) and *A. niger* (17.3 ± 0.57 mm at 12.5 µg/mL), suggesting effective antifungal constituents within the extract. Though the antimicrobial and antifungal activities of *C. amada* were consistently lower than those of standard drugs such as Ciprofloxacin and Fluconazole, the results were statistically significant and scientifically relevant.Overall, these findings support the ethnomedicinal use of *Curcuma amada* in the treatment of microbial infections. The observed antimicrobial activity, particularly against Gram-positive bacteria and fungal strains, indicates that the extract contains bioactive phytochemicals worthy of further isolation, characterization, and therapeutic evaluation. Future studies

should focus on purification of active constituents, mechanism-of-action studies, and potential synergistic effects with conventional antimicrobials to fully explore the pharmacological promise of *C. amada*.

Conflict of Interest

There are no disclosed conflicts of interest.

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