

FORMULATION OF pH SENSITIVE CURCUMIN BASED NAIL POLISH WITH TEA-TREE OIL FOR MANAGEMENT OF ONCHOMYCOSIS

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ABSTRACT

Onychomycosis is one of the most common nail disorders, affecting approximately 50% of all nail consultations worldwide. Conventional topical and systemic antifungal therapies are often limited by poor nail penetration and systemic toxicity. This study aimed to develop a novel, pH-sensitive curcumin-based nail polish formulation containing tea tree oil for the topical management of onychomycosis. Curcumin from *Curcuma longa* and tea tree oil were selected as natural active ingredients due to their established antimicrobial and antifungal properties. The formulation was developed using ethyl cellulose as a film-forming agent, castor oil and propylene glycol as plasticizers, ethyl acetate and ethanol as solvents, and titanium dioxide as an opacifier. Phytochemical screening confirmed the presence of flavonoids, tannins, saponins, alkaloids, and phenolic compounds in the curcumin extract. The formulated nail polish demonstrated satisfactory organoleptic characteristics with a shining appearance, yellow color, and smooth texture. The formulation exhibited the distinctive pH-sensitive color-changing property of curcumin, appearing pale yellow at acidic pH 5.4, yellow at neutral pH 7, and reddish-brown at alkaline pH 9. Stability studies over four weeks showed no significant changes in color, texture, or spreadability. Viscosity measurement yielded 160 cps, indicating suitable consistency for application. The formulation demonstrated significant antimicrobial activity against *Candida albicans*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*, with zone of inhibition values of 11 mm, 15 mm, and 14 mm respectively at high doses. FTIR analysis confirmed the presence of characteristic functional groups of curcumin and formulation components without evidence of chemical incompatibility. This pH-sensitive curcumin-based nail polish represents a promising herbal approach for localized antimicrobial management of onychomycosis, offering a safer alternative to conventional synthetic treatments. However, further investigations including transungual permeation studies, extended stability testing, and in vivo efficacy evaluation are warranted.

KEYWORDS: Onychomycosis, curcumin, pH-sensitive, nail lacquer, tea tree oil, antifungal, transungual delivery.

INTRODUCTION

Onychomycosis and Clinical Significance:



Fig.1 DLSO with Prevalent Yellow Discolouration.



Fig.2 Pigmented DLSO.

Onychomycosis, a fungal infection of the nail plate, represents one of the most prevalent nail disorders globally, accounting for approximately 50% of all nail disease consultations^[1]. The condition affects an estimated 10-12% of the general population worldwide, with incidence increasing with age^[2]. The disease is characterized by nail discoloration, thickening, and deterioration, significantly impacting patients' quality of life and causing cosmetic and psychological distress. Toenails are more frequently affected than fingernails, with the prevalence exceeding 40% in elderly populations.^[1]

Types of onychomycosis:^[2]

- Distal and lateral subungual onychomycosis (DLSO).
- Proximal subungual onychomycosis (PSO).
- Endonyx onychomycosis (EO).
- Total dystrophic onychomycosis (TDO).

Diagnosis of onychomycosis

- The clinical suspect of onychomycosis should be confirmed by mycology. By of direct mycological exam and culture.
- By using KOH 40%, It doesn't allow one to recognize the histopathology of nail clippings can be utilized for diagnosing onychomycosis, with periodic acid-Schiff (PAS)stain that allows easy visualization of fungal hyphae. Digital dermoscopy, also called onchoscopy, is an easy and quick procedure that allows differential diagnosis of onychomycosis from the common nail dystrophies.
- Confocal laser-scanning microscopy (CLSM) is an emerging diagnostic technique The aspect of dermatophytes appears as a network of lengthy structures with high reflection and the typical shape of hyphae: the CLSM aspect of yeasts has been reported by Arrese et al., while molds have not been described yet in nails. Some other interesting new tools in the diagnosis of onychomycosis are: dermatophyte test strip, fluorescence microscopy and Raman spectroscopy.

Treatment of onychomycosis:^[2]

- Treatment depends on the clinical type, number of nails involved, and severity of infection.
- Topical treatment is preferred for mild to moderate onychomycosis.
- Topical antifungal drugs need special formulations to penetrate the nail plate effectively.
- Nail lacquers such as amorolfine 5% and ciclopirox 8% may be used for 6–12 months.
- Periodic removal or trimming of the affected nail can improve treatment effectiveness.
- Re-infection is common, occurring in about 20–25% of patients.
- Systemic antifungal therapy is required for severe infection, proximal nail involvement, or deeply infiltrating disease.
- Terbinafine and itraconazole are commonly used systemic treatments and provide good mycological cure rates.
- Fluconazole may be used as an alternative, but it is generally less effective.
- Posaconazole and albaconazole are newer drugs that may provide alternative treatment options.
- Laser therapy has been studied, but its effectiveness is not yet well established.
- Treatment usually requires several months because nails grow slowly, especially in elderly patients.

Etiological Agents and Treatment Challenges

Onychomycosis is caused primarily by dermatophytes, with *Trichophyton rubrum* and *Trichophyton mentagrophytes* accounting for approximately 90% of cases in many populations.^[3] Non-dermatophyte molds and *Candida* species represent secondary causative agents, particularly in immunocompromised patients. Current treatment approaches are limited by significant constraints: oral antifungal medications (terbinafine, itraconazole, fluconazole) require prolonged courses of 6-12 months and are associated with hepatotoxicity and drug interactions.^[2] Topical therapies, while safer, suffer from poor nail penetration due to the dense, keratinized structure of the nail plate, resulting in subtherapeutic concentrations at the infection site.^[1]

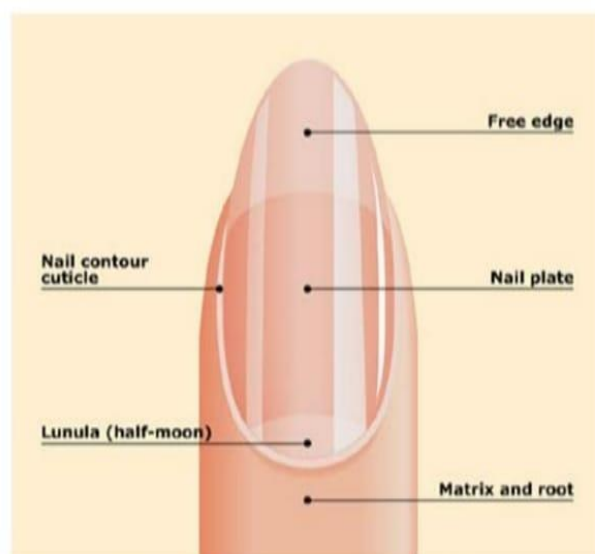
Nail as a Drug Delivery Site

Fig. 3: Schematic representation anatomy of nail.

The nail plate, composed primarily of keratin and tightly packed keratinized cells, presents a formidable barrier to topical drug penetration. Nevertheless, the nail offers unique advantages as a delivery site for localized antimicrobial therapy: the nail provides prolonged contact time with the infection site, reduces systemic absorption and associated toxicity, and allows for convenient self-administration. Nail lacquers designed as transungual delivery systems can maintain prolonged contact between active ingredients and the nail surface, potentially overcoming the limitations of conventional topical formulations.^[4]

Nail Polish:^[1]

Nail polish is a lacquer that can be applied to the human fingernail or toenails to decorate and protect the nail plates. Nail polish consists of a mix of an organic polymer and several other components that give it colour and texture. Nail polish has one of the highest demands in the cosmetic market.

Nail polish is so common among women and even among men now because it's one of the easiest ways to beautify the hands. It can make you feel beautiful and boost your confidence. It can also help cover up flawed or unattractive fingernails or toenail.

What is herbal nail polish? Natural nail polish refers to nail enamel that is free of many of the chemicals commonly found in regular nail polish. Natural nail polish is free of formaldehyde, toluene, artificial colours, xylene and phthalates, all of which are common ingredients in regular nail polish. Plant based active ingredient is the main component of the nail polish which makes it safer than the synthetic ones.

Herbal Nail polishes Available in Market

- DoBelle-Gel nail lacquer (Seaweed extract)
- Just Herbs-12-free nail paint (Jojoba oil, Sweet almond oil)
- Oshea Herbals-Nail enamel (Herbal-positioned product)
- Lotus make-up-Ecostay nail enamel (natural/herbal-positioned range)
- Bella Vita Organic-vibrant colour nail polish (organic/natural-positioned brand)

The ideal nail polish application technique includes the following steps

Base coat-This is the first layer, meant to build up the nail plate. It is clear (transparent) solution with high resin content and major to stronger attachment of nail polish to the nail. It also helps to restores moisture to the nail and helps in the fill up the Ridges and can create a smooth surface.

Nail polish: Colouring nail polish applied as 2–3 coats.

Top coat-Again applied a transparent, clear coat that contains additional nitrocellulose than the 4 resin. This prevents the nail polish from chipping and fail. It added to get shine to the polish. This type of nail polish is a clear coloured polish formula that is used specifically after applying nail polish to the nail. Top coat helps the underlying-colored polish dry quickly as well.

Nail polish drier: Liquid that increase drying of the nail polish by the evaporation of the solvent. Generally, it includes the vegetable oils, alcohols, and the silicone derivatives.

Constituent of nail polish

Film forming agent: Nail polish is applied the solvent evaporates, leaving the polymer to form a film on the nail. Example- Nitrocellulose, dissolved in a solvent, usually ethyl acetate or butyl acetate.

Plasticizers: Nail polish stays flexible, it will be dries, making the nail polish last longer. Example-Dibutyl phthalate and camphor, trimethyl pentanyl di isobutyrate, triphenyl phosphate, ethyl tosylamide, glyceryl tribenzoate.

Adhesive polymer resins: To make sure that the nitrocellulose stick to the nail plate 's surface. Example-1. Tosylamide -formaldehyde resin, 2. A polyester resin or cellulose acetate butyrate in hypoallergenic nail polishes.

Dyes and pigments: The dyes and pigment are imparted in colour. Example-Chromium oxide greens, chromium hydroxide, ferric ferrocyanide, stannic oxide, titanium dioxide, iron oxide, carmine, ultramarine and manganese violet.

Opalescent pigments: Opalescent pigment add glittery or shimmer look. Example – Mica bismuth ox chloride, natural pearls, and aluminium powder.

Thickening agents: The thickening agent used to maintain the sparkling particles in suspension while in the bottle. Example- Stearalkoniumhectorite.

Ultraviolet stabilizers: Ultraviolet stabilizer is used to resist colour changes when the dry film is exposed to sunlight. Example- Benzophenone-1

Ideal characteristics of a nail polish

- Nail polish has proper viscosity, flow and wetting properties.
- It must have uniform color.
- It must have good adhesive and gloss properties.
- Nail polish has sufficient flexibility.
- Nail polish has sufficient hard surface which is resistant to impact and scratch.
- Nail polish has reasonable drying time.
- It should be convenient and easy to apply.
- It should be stable on storage.
- It should form a satisfactory film on nails.

Advantages of nail polish

- Prevent the nail from scratches.
- Improve strength of nails.
- It used to prevent growth of fungus and bacteria.
- It used to beautify hands.
- It is long lasting.
- It is not damage to the nail.
- It is easy to remove.
- It is time saving.

- It is no smudge.
- Nail polish looks natural on your nails.

Disadvantages of nail polish

- Superficial nail discoloration.
- pseudo- Leukonychia,
- Allergic contact dermatitis (local and distal)
- Microbial colonization,
- Distorted pulse oximetry readings
- Methacrylate sensitization and cross-reactivity,
- Rhinitis/wheezing,
- Nail brittleness
- Thinning
- Flammability
- Mask nail bed

Drawbacks of synthetic nail polish

- Thins natural nails and makes them weaker.
- Chemicals irritate the skin around the nails; they are absorbed into the skin and blood stream.
- Synthetic colors used, causing neurotoxic and carcinogenic effect.
- Readily dries on skin and makes it dehydrated.
- Often causes allergic reactions.
- Chemicals like toluene, formaldehyde, dibutyl phthalate are toxic to the environment
- Toxic effect on body:
- Toluene – irritant to skin and causes tiredness, confusion, memory loss.
- Formaldehyde – a known carcinogen.
- Camphor – cause yellowing of nail by stripping off its nutrients.

Benefits of herbal nail polish

- Thicker, stronger, more durable nails
- Brittle free nails.
- Chip-resistant nails.
- Moisturized, hydrated nails
- Break resistance
- Scratch and water resistant

Disorders of nail

- Leukonychia
- Koilonychias
- Disorders due to systemic disease

- Brittleness
- Disorders due to fungal and bacterial origin-paronychia nail ring worm lesions due to syphilis
- Disorders due to nutrient deficiency
- Stippled nails.
- Onychomycosis.

Rationale for Herbal Approach:

Recent pharmaceutical research has increasingly focused on natural compounds with proven antimicrobial properties. Curcumin, the major active constituent of *Curcuma longa* (turmeric), possesses well-documented antifungal, antibacterial, and anti-inflammatory properties.^[5]

Curcumin's mechanism of action against fungal pathogens involves disruption of the fungal cell membrane and interference with cellular processes.^[6] Additionally, curcumin exhibits a distinctive pH-sensitive color-changing property, shifting from yellow in acidic conditions to reddish-brown in alkaline conditions, offering a unique indicator of the chemical microenvironment.^[7] Tea tree oil (*Melaleuca alternifolia*), another traditional remedy, contains terpinen-4-ol as its active component and demonstrates broad-spectrum antimicrobial activity against resistant pathogens including MRSA and *Candida* species.^[8] The combination of these two natural agents provides synergistic antimicrobial coverage while minimizing reliance on synthetic chemicals, thereby addressing growing patient concerns about chemical toxicity in cosmetic and pharmaceutical preparations.^[9]

Study Objectives

This study was designed to:

- (1) develop and optimize a pH-sensitive curcumin-based nail polish formulation incorporating tea tree oil as an adjunctive antimicrobial agent;
- (2) characterize the physicochemical properties of the formulation;
- (3) evaluate its antimicrobial activity against clinically relevant pathogens;
- (4) assess stability and suitability for pharmaceutical application; and
- (5) provide a safer, herbal alternative to conventional synthetic nail lacquers for onychomycosis management.

pH Sensitivity of Curcumin:

One of the distinctive properties of curcumin is its P^H -dependent colour response. Curcumin generally appears yellow in acidic to near-neutral conditions. When the P^H increases into alkaline conditions, the colour can shift toward orange and reddish shades. This phenomenon is associated with ionization of the phenolic groups and changes in the electronic structure of the curcumin molecule.

A simplified experimental colour progression may be represented as:

Table 1: pH Sensitivity of curcumin.

pH	Approximate expected colour
2-4	Yellow
5-6	Yellow/Golden Yellow
7	Yellow-Yellow Orange
8	Yellow-Orange/ Orange
9	Orange
10	Orange to Reddish Orange

11	Reddish / Orange Brown
12	Reddish-Brown/Dark Brown

These colours are approximate because the observed colour depends on curcumin concentration, solvent, buffer composition, film thickness, temperature, formulation components, and observation time. The colour change observed during P^H evaluation is a characteristic property of curcumin and does not indicate instability. Stability concerns arise only when irreversible colour changes occur during storage under controlled conditions.

Conventional nail polish is primarily a cosmetic preparation designed to provide colour, shine, and protection. Pharmaceutical nail lacquers, however, can be designed as drug-delivery systems. After application, the volatile components of the formulation evaporate and leave a film containing the active ingredient. This film can maintain prolonged contact between the active substance and the nail surface. Such systems are referred to as transungual drug-delivery systems.

Nail lacquers are particularly useful in onychomycosis because they can increase residence time and facilitate gradual movement of the active substance through the nail. Topical therapy is generally more appropriate for selected mild-to-moderate diseases, while extensive disease or matrix involvement may require systemic comb.

MATERIALS AND METHODS

Plant Material and Chemicals

Dried rhizomes of *Curcuma longa* were procured from a local supplier in Madurai, Tamil Nadu, India, and authenticated according to standard pharmacognostic procedures. Tea tree oil (*Melaleuca alternifolia*) was obtained from commercial sources. Excipients including ethyl cellulose, ethyl acetate, propylene glycol, titanium dioxide, ethanol, methanol, petroleum ether, and chloroform were procured from Bharath Chemicals, Madurai, India. Castor oil was obtained from local pharmaceutical suppliers. All chemicals were of analytical or pharmaceutical grade.

EXPERIMENTAL WORK

COLLECTION AND EXTRACTION OF HERBS:^[1]

1. TURMERIC

COLLECTION OF HERBS:

The plant of turmeric was collected from the local market.



Fig. 4: Extraction of turmeric extraction method.^[1]

The extraction process of Curcumin

Step: 1

Add 5gm of powder with 50ml petroleum ether in a beaker.

The solution stirred for 5minutes.

Magnetic stirred for 15 minutes

Filtered and discard the filtrate and the obtained residue was allowed to dry.

Step: 2

Dry residue and add 50ml chloroform

Stirred for 5min and keep on magnetic stirred for an about 15min

Filter and discard the filtrate and the residue was allowed to dry.

Step: 3

Stirred for 5min and allowed to keep on magnetic stirrer for an about 15 min extraction of Curcumin from curcuma longa. The solution was filtered. Concentrate the filtrate and residue dissolution methanol.

Method for preparation of pH sensitive curcumin-based nail polish with tea tree oil for management of onychomycosis

The rhizome of Curcuma longa is first properly authenticated and identified to ensure the quality and authenticity of the raw material. It is then thoroughly washed to remove dirt and impurities, dried completely, and ground into a fine, uniform powder. The powdered rhizome is subjected to extraction of curcumin using chloroform, petroleum ether, and methanol as suitable solvents.

The obtained curcumin extract is taken in the required quantity in a clean beaker and stirred properly using a magnetic stirrer to obtain a uniform extract. In a separate beaker, the required amount of ethyl cellulose is dissolved in ethyl acetate and slowly transferred into the curcumin extract with continuous mixing. Next, the required quantities of castor oil and tea tree oil are mixed well in a separate beaker and added to the formulation, where they help to improve flexibility and act as plasticizing agents. Propylene glycol is then incorporated as an additional plasticizer, while titanium dioxide is added as a shining or gloss-enhancing agent. The required quantity of ethanol is also added to improve the consistency and proper mixing of the formulation.

The complete mixture is then stirred thoroughly using a magnetic stirrer for sufficient time to ensure uniform distribution of all ingredients and to obtain a smooth, homogeneous formulation. Finally, the prepared herbal nail polish is carefully transferred into a clean, dry, airtight glass container to protect it from contamination and evaporation and is stored under suitable conditions until further use.

Composition of curcumin nail polish

Table 2: Composition of curcumin nail polish.

S. No	Ingredients	Quantity For (50ml)	Uses
1	Curcumin Extract	0.5ml	Anti-Inflammatory
2	Ethyl Cellulose	3.3gm	Binder, Thickener
3	Ethyl Acetate	28ml	Film Forming Agent
4	Castor Oil	0.75ml	Plasticizer
5	Tea Tree Oil	2.5ml	Anti-Fungal and Anti-Bacterial Agent

6	Ethanol	14ml	Solvent, Viscosity Adjuster
7	Propylene Glycol	0.75ml	Plasticizer
8	Titanium Di Oxide	0.2gm	Shinning Agent



Fig. 5: Formulation of pH Sensitive Curcumin Based Nail Polish with Tea Tree Oil For management of Onchomycosis

EVALUATION PARAMETRS OF CURCUMIN NAIL POLISH:^[8]

Preliminary phytochemical test

Table 3: Preliminary Phytochemical Test.

S. No	Test	Procedure	Observation	Reference
1.	Test for Flavonoids.	Take 2ml of extract, add few drops of sodium hydroxide (NaOH) solution then add dilute acid Hcl	Yellow colour appears with NaOH	Presence of Flavonoids
2.	Test for Tannins.	Take 2ml of extract, add few drops of 5% FeCl ₃ solution	Black colour	Presence of Tannins
3.	Test for Saponins.	Take 2ml extract, add stable distilled water, shake vigorously for 2 to 3 min	Stable persistent foam formed	Presence of Saponin
4.	Test for Alkaloids.	Take 2ml extract, add few drops of mayor's reagent	Creamy precipitate form	Presence of Alkaloids
5.	Test for Phenolic Compounds.	Take 2ml extract, add few drops of FeCl ₃	Green color	Presence of Phenolic Compounds

EVALUATION PARAMETRS OF CURCUMIN NAIL POLISH:^[8]

Physical appearance

To determine the physical appearance, we must observe the following characteristics: colour, texture, and consistency. Observe the colour, texture, and consistency of nail polish with naked eyes.

Drying time

To determine the time taken for the nail polish to dry completely after application.

Gloss/finish

To evaluate the shine or matte finish of the nail polish after drying.

Durability/ long-lasting

To determine how long the nail polish stays intact without chipping or fading.

Adherence to nail

This test is performed to evaluate the ability of the nail polish to stick to the nail surface without peeling.

Flexibility

To determines if the nail polish cracks or peels when the nail bends or moves.

Stability

The formulation was kept at room temperature for one week. After one week, the pH, homogeneity, and colour of the formulation were evaluated and compared with the initial observation.

Smudge Resistance

The resistance of the nail polish to smudging before it is fully dried.

Scratch Resistance

To measures the ability of the nail polish to resist scratches from daily activities.

Toxicity

This test is performed to ensure that the nail polish is free from harmful chemicals and safe for use.

Ease-of-Application

This test is performed to Assesses how easily the polish applies, such as smoothness, no clumping, etc.

Colour Retention

This test is performed to measure how-long the Colour stays intact and vibrant over time.

Viscosity

To determine the thickness or flow characteristics of the nail polish using Brookfield Viscometer.

Spreadability Test:

Weight a small amount of nail polish about 1ml, then place the nail polish on the top of the glass slide and place another glass slide on the top of the nail polish.

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

Where, S =Spreadability

M =Weight tied to upper slide(g) L =Length moved(cm)

T =Time taken

Anti-Microbial Activity

Nutrient agar medium was used for the antimicrobial assay. The nutrient agar was prepared according to the prescribed procedure and sterilized by autoclaving at 121 °C for 45 minutes. after sterilization, the medium was allowed to cool to 37 °C to 38 °C and then pour into sterile petri plates. the plates were allowed to solidify. After solification, subculture

microorganisms were inoculated onto the surface of the nutrient agar plates by the streaking method and subjected to incubation. Four wells were then made on each plate using a sterile borer. The individual polyherbal formulation, marketed formulation (test sample), and standard reference were introduced into the respective wells. The plates were kept for incubation at 37 °C for 24 hours to allow microbial growth. After incubation, the antimicrobial activity was evaluated by measuring the zone of inhibition and the results were recorded.

RESULT AND DISCUSSION

Phytochemical Screening

The result of phytochemical screening for curcumin extract was given below:

Table 4: Phytochemical Test.

S. No	Phytochemical Compounds	Curcumin Extract
1	Flavonoids	✓
2	Tannins	✓
3	Saponins	✓
4	Alkaloids	✓
5	Phenolic Compounds	✓

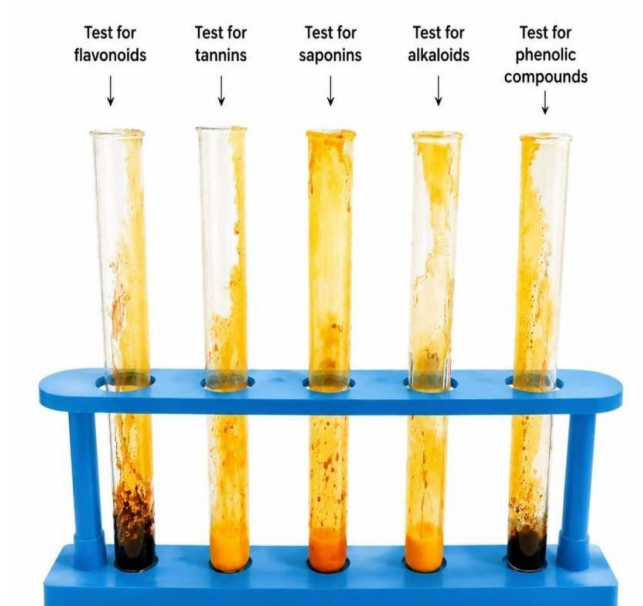


Fig. 6: Phytochemical Test of Curcumin Extract.

Organoleptic Parameters

The physical appearance, colour and texture of the prepared curcumin nail polish are visually tested.

Table 5: Organoleptic Parameters.

S. No	Organoleptic Parameters	Result
1	Physical appearance	Shinning
2	Colour	Yellow
3	Texture	Smooth

**Fig. 7: Herbal Nail Polish.****Fig. 8: Organoleptic Test.**

Discussion

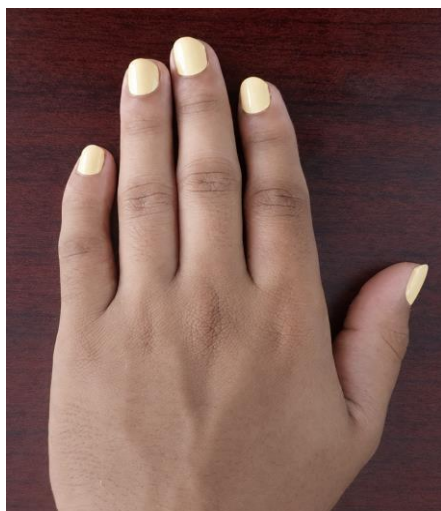
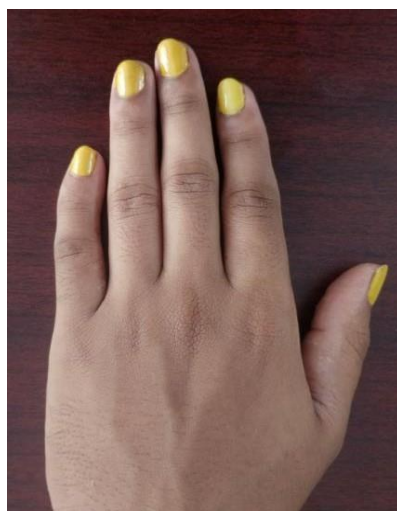
The organoleptic evaluation revealed that the formulation possessed a yellow colour, shining and smooth texture, indicating good physical appearance and uniformity.

pH Determination

The colour change observed during pH evaluation is a characteristics property of curcumin and doesn't indicate instability. Stability concerns arise only when irreversible colour changes occur during storage under controlled conditions.

Table 6: pH Determination.

S. No	pH Range	Result
1	Acidic	Pale Yellow
2	Neutral	Yellow
3	Alkaline	Reddish Brown

**Fig. 9: Acidic pH.****Fig. 10: Neutral pH.****Fig. 11: Alkaline pH.**

Stability

The short-term evaluation was conducted by observing colour, texture, and spreadability of the prepared formulation at pre-determined time intervals of 1,2,3 and 4 weeks.

Table 7: Stability Testing.

S. No	Weeks	Observation		
		Colour	Texture	Spreadability
1	1week	No change	No change	No change
2	2weeks	No change	No change	No change
3	3weeks	No change	No change	No change
4	4weeks	No change	No change	No change

Discussion

The stability study indicated that the formulation remained physically stable during the one-month observation period. No change in colour were observed, suggesting absence of degradation or ingredient incompatibility. The texture remains constant, indicating chemical stability and suitability for application. Formulation maintained uniform homogeneity without phase separation, confirming the effectiveness of the selected formulation components.

Viscosity

The viscosity of the prepared herbal nail polish was calculated using the Brookfield viscometer.

$$\eta = \text{Dial reading} \times \text{Factor}$$

were,

$$\eta = \text{viscosity of the sample (cps)}$$

Dial Reading = reading shown by the Brookfield viscometer

Factor = spindle/speed factor specified for the particular Brookfield model, spindle and RPM.

Table 8: Viscosity Test.

S. No	Viscosity
1.	160 cps

Discussion

The obtained viscosity indicated that the formulated herbal nail polish possessed suitable consistency, ensuring ease of spreading and good stability.

Antimicrobial activity

1. The Antimicrobial activity of the given sample Nail polish against *Candida albicans*:

Table 9: Nail Polish Formulation Against *Candida Albicans*.

S. No	Microbial strains	Concentration in $\mu\text{g/ml}$ & Zone of Inhibition in (mm)		
		Fluconazole	Low Dose	High Dose
1	<i>Candida albicans</i>	12	8	11



Fig. 12: Nail Polish Formulation Against *Candida Albicans*.

2. The Antimicrobial activity of the given sample Nail polish against *Staphylococcus aureus*:

Table 10: Nail Polish Formulation against *Staphylococcus Aureus*.

S. No	Microbial strains	Concentration in $\mu\text{g/ml}$ & Zone of Inhibition in (mm)		
		Ciprofloxacin	Low Dose	High Dose
1	<i>Staphylococcus aureus</i>	40	10	15



Fig. 13: Nail Polish Formulation against *Staphylococcus Aureus*.

3. The Antimicrobial activity of the given sample Nail polish against *Pseudomonas aeruginosa*:

Table 11: Nail Polish Formulation against *Pseudomonas Aeruginosa*.

S. No	Microbial strains	Concentration in $\mu\text{g/ml}$ & Zone of Inhibition in (mm)		
		Tetracycline	Low Dose	High Dose
1	<i>Pseudomonas aeruginosa</i>	18	10	14

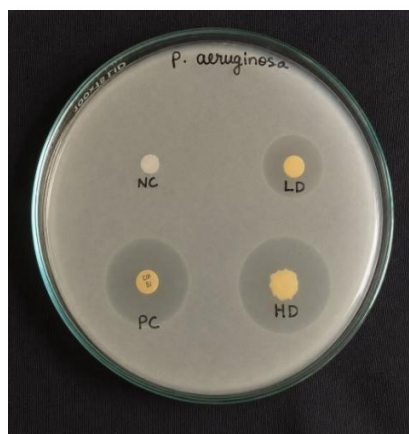


Fig. 14: Nail Polish Formulation against *Pseudomonas Aeruginosa*.

The antimicrobial activity of the nail polish sample was evaluated against *Candida albicans*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* by measuring the zone of inhibition around the low-dose and high-dose samples.

Table 12: Results of Anti-Microbial Activity.

Test Organism	Positive Control (mm)	Low-Dose Nail Polish (mm)	High-Dose Nail Polish (mm)
<i>Candida albicans</i>	12	8	11
<i>Staphylococcus aureus</i>	40	10	15
<i>Pseudomonas aeruginosa</i>	18	10	14

DISCUSSION

The results demonstrate that the tested nail polish possessed antimicrobial activity against both Gram-positive and Gram-negative as well as the yeast *C. albicans*. The antimicrobial effect increased with increasing nail polish dose. The strongest activity was observed against *Staphylococcus aureus*, followed by *Pseudomonas aeruginosa* and *Candida albicans*. These findings suggest that the nail polish formulation has potential antimicrobial properties under the experimental conditions tested.

FTIR Analysis Report:

1. Nail Polish – Standard Curcumin

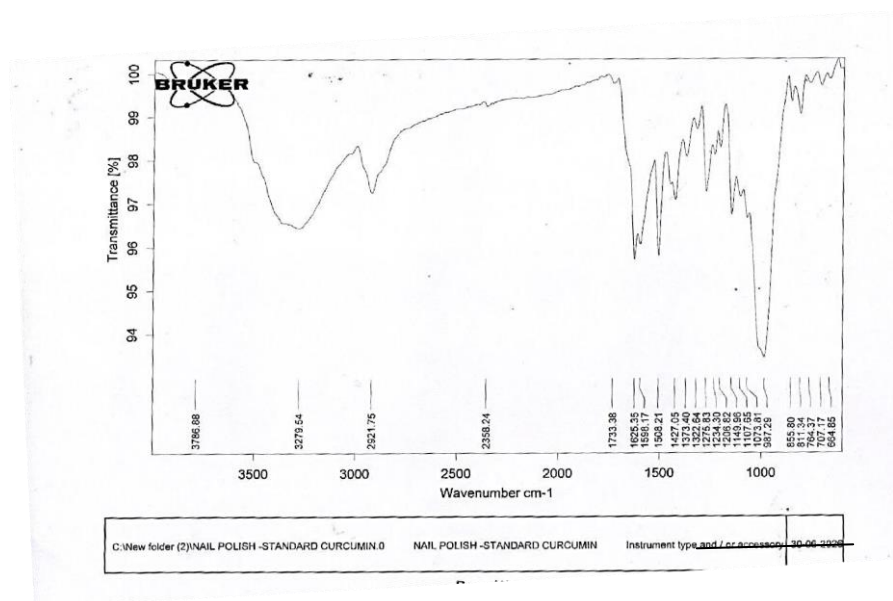


Fig. 15: FTIR of Standard Curcumin.

Table 13: FTIR of Standard Curcumin.

Wavenumber (cm ⁻¹)	Functional Group	Interpretation
3279.54	O–H Stretching	Phenolic hydroxyl group
2921.75	C–H Stretching	Aliphatic C–H vibration
1733.38	C=O Stretching	Conjugated carbonyl group
1625.85	C=C / C=O Stretching	Conjugated enone structure
1598.17	Aromatic C=C Stretching	Aromatic ring vibration
1508.21	Aromatic Skeletal Vibration	Benzene ring conformation
1487.40	CH ₂ Bending	Aliphatic bending vibration
1823.64 – 1204.30	C–O Stretching	Phenolic and methoxy groups
1168.92 – 1023.29	C–O–C Stretching	Ether group
855.84 – 664.85	Aromatic C–H Bending	Substituted aromatic ring

Discussion

The FTIR spectrum of standard curcumin showed characteristic peaks corresponding to phenolic hydroxyl (O–H), conjugated carbonyl (C=O), aromatic (C=C), methoxy (C–O–C) and phenolic C–O functional groups. These peaks are consistent with the reported FTIR spectrum of pure curcumin. The presence of these characteristic absorption bands confirms the chemical identity of curcumin and indicates the purity of curcumin.

Nail Polish – Turmeric – Methanol Extract

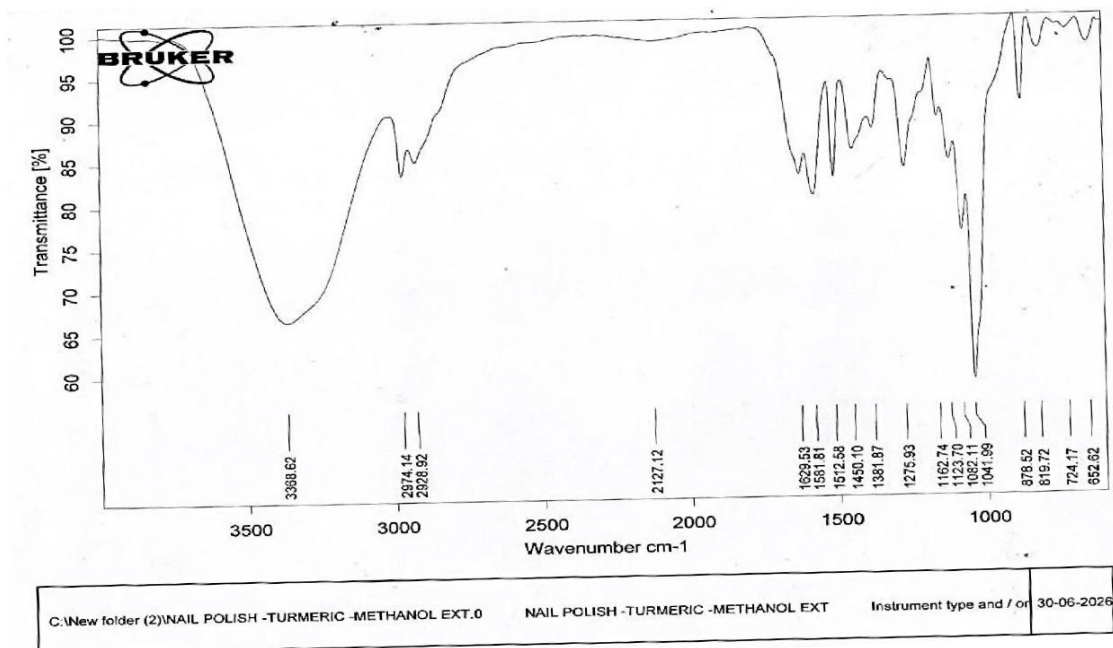


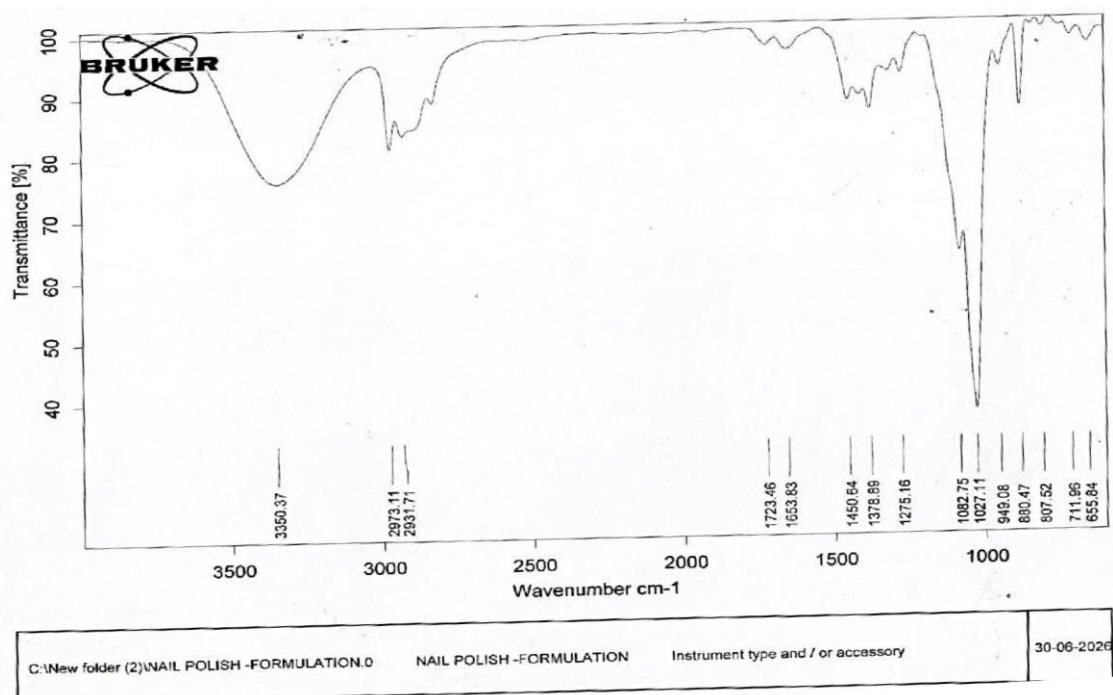
Fig. 16: FTIR of Turmeric – Methanol Extract.

Table 14: FTIR of Turmeric – Methanol Extract.

Wavenumber (cm ⁻¹)	Functional Group	Interpretation
3366.62	O–H Stretching	Phenolic hydroxyl group of curcumin
2974.14, 2928.92	C–H Stretching	Aliphatic C–H stretching vibrations
1629.53	C=O / C=C Stretching	carbonyl and aromatic double bond of curcumin
1595.81	Aromatic C=C Stretching	Aromatic ring vibration
1512.58	Aromatic Skeletal Vibration	Benzene ring stretching
1450.10	CH ₂ Bending	Methylene bending vibration
1381.87	C–H Bending	Methyl group deformation
1275.93	C–O Stretching	Phenolic C–O stretching
1163.27, 1122.70	C–O–C Stretching	Ether linkage vibration
1082.19, 1041.99	C–O–C Stretching	Alcohol/ether functional groups
878.52, 819.72	Aromatic C–H Bending	Out-of-plane aromatic bending
724.17, 652.62	Fingerprint Region	Aromatic ring deformation

Discussion

The FTIR spectrum confirms the presence of the characteristic functional groups of curcumin, including the phenolic O–H group, conjugated carbonyl (C=O), aromatic C=C bonds, and ether (C–O–C) groups. These characteristic peaks indicate that the methanolic turmeric extract has been successfully incorporated into the nail polish formulation. No major shifts or disappearance of the characteristic peaks were observed, suggesting that curcumin remains chemically stable and is compatible with the excipients used in the nail polish formulation.

FTIR Report – Nail Polish Formulation:**Fig. 17: FTIR of Nail Polish Formulation.****Table 15: FTIR of Nail Polish Formulation.**

Wavenumber (cm ⁻¹)	Functional Group	Interpretation
3350.87	O–H Stretching	Phenolic hydroxyl group (curcumin)
2973.11	C–H Stretching	Aliphatic C–H of methyl/methylene group
2931.71	C–H Stretching	Aliphatic hydrocarbon chain
1723.46	C=O Stretching	Ester carbonyl group (ethyl acetate/plasticizer)
1653.83	C=C Stretching	Conjugated double bond of curcumin
1450.64	CH ₂ Bending	Methylene group vibration
1378.89	CH ₃ Bending	Methyl group vibration
1275.16	C–O Stretching	Ether/ester linkage of ethyl cellulose
1082.75	C–O–C Stretching	Ether linkage of polymer
1027.11	C–O Stretching	Alcohol/ether functional group
930.08	=C–H Bending	Alkene vibration
880.47	Aromatic C–H Bending	Aromatic ring vibration
807.52	Aromatic C–H Bending	Substituted aromatic ring
711.96	Aromatic C–H Bending	Fingerprint region
656.84	Fingerprint Region	Characteristic aromatic vibration

Discussion

The FTIR analysis confirmed the presence of characteristic functional groups corresponding to curcumin, ethyl cellulose, castor oil, and ester-based solvent components. In the nail polish formulation, the absence of significant peak shifts or new absorption bands indicates that the formulation components are chemically compatible.

Study Limitations and Future Directions

While the present study demonstrates promising results, several limitations warrant discussion. This investigation focused on *in vitro* antimicrobial activity; *in vivo* efficacy evaluation in affected patients is necessary to establish clinical relevance. Transungual permeation studies are essential to confirm penetration of active ingredients through the nail plate to reach the infection site.

Extended stability studies under various storage conditions and long-term efficacy evaluation across multiple nail disease models would strengthen the clinical evidence base. Future investigations should include: (1) comparative efficacy studies against standard antimicrobial treatments; (2) safety and tolerability assessment in human subjects; (3) pharmacokinetic studies to determine nail penetration and bioavailability; (4) development of optimized formulations for specific disease subtypes and severity levels; and (5) regulatory pathway evaluation for pharmaceutical registration and marketing authorization.

SUMMARY AND CONCLUSION

The present research work was carried out with the aim of developing a **“P^H-SENSITIVE CURCUMIN-BASED NAIL POLISH CONTAINING TEA TREE OIL FOR THE MANAGEMENT OF ONCHOMYCOSIS”**. Onchomycosis is a common fungal infection of the nails, and conventional topical treatment may be limited by the barrier properties of the nail plate and inadequate drug penetration. Therefore, a nail lacquer-based transungual drug-delivery approach was selected to provide prolonged contact of the active ingredients with the nail surface.

Curcumin obtained from *Curcuma longa* was selected as the major herbal active ingredient because of its reported antimicrobial and antifungal properties. Tea tree oil was incorporated as an additional natural antimicrobial component. The formulation was developed using suitable excipients including ethylcellulose as a film-forming polymer, castor oil and propylene glycol as plasticizing components, ethyl acetate and ethanol as solvents, and titanium dioxide as an opacifying/shining component. The ingredients were mixed thoroughly to obtain a smooth and homogeneous nail polish formulation.

Preliminary phytochemical screening of the Curcumin extract showed the presence of flavonoids, tannins, saponins, alkaloids and phenolic compounds. These findings supported the presence of bioactive phytoconstituents in the prepared extract. The prepared nail polish showed satisfactory organoleptic characteristics. It exhibited a shining appearance, yellow color and smooth texture, indicating acceptable physical appearance and uniformity.

The formulation demonstrated the desired P^H-sensitive color-changing property of Curcumin. At P^H 5.4, the formulation appeared pale yellow; at neutral P^H 7, it remained yellow, while at alkaline P^H 9, it changed to reddish brown. This colour response represents the characteristic P^H-dependent behaviour of curcumin. The Short-term Stability study showed that the formulation remained physically stable for 4 weeks. No noticeable changes in colour, texture (or) spreadability were observed during the observation period, and the formulation remained homogeneous without phase separation.

The formulated nail polish exhibited a viscosity of 160cP, indicating suitable consistency for smooth spreading and application over the nail surface. The formulation showed antimicrobial activity against *Candida albicans*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*. FTIR analysis showed the characteristic functional groups of curcumin and the formulation components. The absence of significant peak shifts (or) new peaks indicated good chemical compatibility and no major interaction among the formulation ingredients. The developed formulation can be considered a promising herbal nail-polish-based approach for localized antimicrobial management of onchomycosis. However, further investigations such as transungual permeation studies, extended stability studies, safety evaluation are required to establish its therapeutic effectiveness and safety.

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