Formulation And Evaluation of Curcumin Nanosuspention Gel for Anti-Inflammatory Activity

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***Abstract*—Curcumin, a naturally occurring polyphenolic compound obtained from Curcuma longa, possesses significant anti-inflammatory, antioxidant, antimicrobial, and wound-healing properties. However, its therapeutic application is greatly limited due to poor aqueous solubility, low permeability, rapid metabolism, and poor oral bioavailability. The present study was aimed at the formulation and evaluation of a curcumin nanosuspension-loaded gel for enhanced bioavailability and improved therapeutic efficacy through topical delivery.**

Curcumin nanosuspension was prepared using the nanoprecipitation/high-speed homogenization method with suitable stabilizers and surfactants to reduce particle size and improve drug dispersion. The prepared nanosuspension was evaluated for particle size, polydispersity index, zeta potential, drug content, entrapment efficiency, and in vitro drug release. The optimized nanosuspension exhibited nanosized particles with uniform distribution, good stability, and enhanced dissolution behavior compared to pure curcumin. The optimized curcumin nanosuspension was further incorporated into a gel base using suitable gelling agents to obtain a stable topical formulation. The prepared gel formulations were evaluated for physical appearance, pH, viscosity, spreadability, homogeneity, drug content, extrudability, and stability studies. In vitro diffusion studies demonstrated sustained and enhanced release of curcumin from the nanosuspension gel formulation. Ex vivo permeation studies indicated improved skin penetration and bioavailability due to the nanosized drug particles and increased surface area. The results of the study confirmed that nanosuspension-based gel formulation significantly improved the solubility, dissolution rate, and topical bioavailability of curcumin compared to conventional formulations. Hence, the developed curcumin nanosuspension gel may serve as a promising drug delivery system for effective topical therapy with enhanced therapeutic performance and patient compliance.

***Index Terms*—Curcumin, Nanosuspension, Gel, Bioavailability, Topical Drug Delivery, Nanotechnology, In Vitro Release, Skin Permeation.**

I. INTRODUCTION

1.1 Introduction to Inflammation

Inflammation is a natural protective response of the body that occurs when tissues are injured due to infection, trauma, toxins, physical damage, or harmful irritants. It is an essential part of the immune system that helps the body to eliminate the harmful cause of injury, remove damaged cells, and initiate the healing process.

When the body detects injury or infection, immune cells such as white blood cells become activated and release chemical mediators like histamine, prostaglandins, cytokines, and leukotrienes. These mediators cause changes in blood vessels and tissues, leading to the typical signs of inflammation such as redness, swelling, heat, pain, and loss of function.

Inflammation is a complex biological process involving multiple cells, enzymes, and signaling pathways. Because of its role in many diseases, it is one of the most important targets in modern pharmaceutical research.

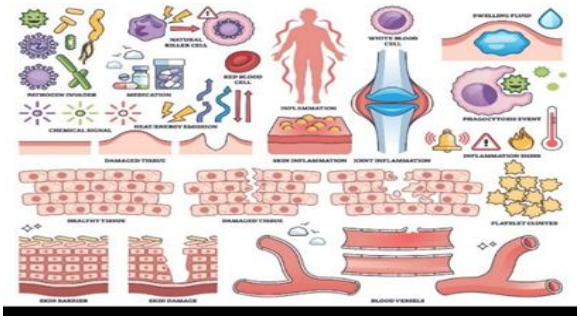

Fig.1 Inflammation

1.2Types of Inflammation

1. Acute Inflammation

Acute inflammation is a short-term and immediate response of the body to injury, infection, or harmful stimuli. It usually lasts for a few hours to a few days.

Features:

- Rapid onset
- Short duration
- Redness, swelling, heat, pain
- Involves neutrophils (white blood cells)

Examples:

- Cut or wound
- Bacterial infection
- Burns

2. Chronic Inflammation

Chronic inflammation is a long-term inflammatory response that may last for weeks, months, or years. It occurs when the body fails to eliminate the cause of inflammation.

Features:

- Slow onset
- Long duration
- Tissue damage and fibrosis
- Involves macrophages and lymphocytes

Examples:

- Arthritis
- Asthma
- Diabetes
- Cancer

3. Sub-acute Inflammation

Sub-acute inflammation is an intermediate stage between acute and chronic inflammation.

Features:

- Longer than acute
- Not as severe as chronic
- Moderate tissue damage

4. Localized Inflammation

Localized inflammation occurs in a specific area of the body.

Examples:

- Skin infection
- Abscess
- Minor injury

5. Systemic Inflammation

Systemic inflammation affects the entire body and can become life-threatening.

Examples:

- Sepsis
- Severe infections
- Autoimmune disorders

1.3Mechanism of Inflammation

Inflammation is a complex biological process that occurs in response to tissue injury, infection, toxins, or physical damage. It involves a series of vascular, cellular, and chemical events that help the body remove harmful stimuli and start tissue repair.

The mechanism of inflammation can be explained in the following steps:

1. Tissue Injury (Triggering Event)

Inflammation starts when tissues are damaged due to:

- Infection (bacteria, virus)
- Physical injury (cut, burn)
- Chemical irritants
- Toxins

This injury activates immune cells and damaged tissues.

2. Release of Chemical Mediators

Damaged cells and immune cells release inflammatory mediators such as:

- Histamine
- Prostaglandins
- Bradykinin
- Cytokines (TNF-α, IL-1, IL-6)
- Leukotrienes

These chemicals initiate and control inflammation.

3. Vasodilation (Blood Vessel Expansion)

Blood vessels near the injury site widen.

Effects:

- Increased blood flow
- Redness (rubor)
- Heat (calor)

4. Increased Vascular Permeability

Blood vessels become more permeable.

Effects:

- Fluid leaks into tissues
- Swelling (edema)
- Pain due to pressure on nerves

5. Migration of White Blood Cells (Leukocyte Movement)
White blood cells move from blood vessels to the injury site.
Process:
- Neutrophils arrive first (acute inflammation)
- Macrophages follow (chronic inflammation)
- They destroy pathogens and remove dead cells

6. Phagocytosis (Destruction of Harmful Agents)
- White blood cells engulf and destroy:
- Bacteria
- Dead cells
- Foreign particles

This helps in cleaning the injured area.
7. Resolution and Tissue Repair
After removal of harmful agents:
- Inflammation reduces
- New tissue formation begins
- Collagen is produced
- Healing occurs

1.4Anti-inflammatory Activity
Anti-inflammatory activity refers to the ability of a substance (drug or natural compound) to reduce, control, or suppress inflammation in biological tissues. It works by inhibiting the production or action of inflammatory mediators that are responsible for causing swelling, pain, redness, and tissue damage.

Mechanism of Anti-inflammatory Activity
Anti-inflammatory agents work through different mechanisms such as:
1. Inhibition of Prostaglandin Synthesis
- Blocking cyclooxygenase enzymes (COX-1 and COX-2)
- Reduces prostaglandins responsible for pain and swelling

2. Suppression of Cytokines
- Decreases TNF-α, IL-1, IL-6 production
- Reduces immune cell activation and inflammation

3. Inhibition of Lipoxygenase Pathway
- Reduces leukotriene formation
- Helps in controlling allergic and inflammatory reactions

4. Stabilization of Cell Membranes
- Prevents release of lysosomal enzymes
- Reduces tissue damage

5. Antioxidant Activity
- Scavenges free radicals
- Protects tissues from oxidative stress-induced inflammation

1.5Natural Anti-inflammatory Agents
Natural anti-inflammatory agents are bioactive compounds obtained from plants, herbs, and natural sources that help in reducing inflammation with comparatively fewer side effects than synthetic drugs. These agents are widely used in traditional systems of medicine such as Ayurveda, Unani, and Chinese medicine.
Mechanism of Natural Anti-inflammatory Agents
Natural compounds show anti-inflammatory activity through:
- Inhibition of COX and LOX enzymes
- Suppression of NF-κB signaling pathway
- Reduction of cytokines (TNF-α, IL-1, IL-6)
- Antioxidant activity (free radical scavenging)
- Stabilization of cell membranes

Important Natural Anti-inflammatory Agents
1. Curcumin
Obtained from Curcuma longa
- Strong anti-inflammatory and antioxidant agent
- Inhibits COX-2, NF-κB, and cytokines
- Useful in arthritis, wound healing, and chronic inflammation

2. Piperine
Obtained from Piper nigrum
- Enhances bioavailability of curcumin
- Has mild anti-inflammatory and antioxidant effects

Advantages of Natural Anti-inflammatory Agents
- Fewer side effects
- Safe for long-term use
- Antioxidant properties
- Multiple mechanisms of action
- Useful in chronic inflammatory diseases

1.6Introduction to Curcumin

Curcumin is a natural polyphenolic bioactive compound widely known for its strong anti-inflammatory, antioxidant, antimicrobial, and wound healing properties. It is the principal active constituent responsible for the yellow color of turmeric and has been extensively used in traditional medicine for the treatment of various diseases.

Fig.2 Curcumin

Curcumin is obtained from the rhizomes of Curcuma longa, commonly known as turmeric. It belongs to the curcuminoid family and is chemically known as diferuloylmethane. It has been used for centuries in Ayurvedic and Chinese medicine for treating inflammation, skin diseases, infections, wounds, and digestive disorders.

Advantages of Curcumin

- Natural and safe compound
- Multi-target therapeutic action
- Strong antioxidant property
- Effective in chronic inflammatory diseases
- Wide medicinal use in traditional systems

1.2 Pharmacological Activities of Curcumin

Curcumin is a biologically active polyphenolic compound obtained from the rhizomes of Curcuma longa. It exhibits a wide range of pharmacological activities, which make it an important natural therapeutic agent in modern pharmaceutical research.

1. Anti-inflammatory Activity

Curcumin is a strong anti-inflammatory agent. It reduces inflammation by:

- Inhibiting COX-2 and LOX enzymes
- Suppressing NF-κB pathway
- Reducing cytokines such as TNF-α, IL-1, and IL-6
- Decreasing prostaglandin synthesis

This helps in reducing pain, swelling, and tissue damage.

2. Antioxidant Activity

Curcumin acts as a powerful antioxidant by:

- Scavenging free radicals
- Increasing antioxidant enzyme activity (SOD, catalase, glutathione)
- Preventing oxidative stress

This protects cells from damage caused by reactive oxygen species (ROS).

3. Antimicrobial Activity

Curcumin shows activity against:

- Bacteria
- Fungi
- Viruses

It helps in preventing infection and supports wound healing.

4. Anticancer Activity

Curcumin has shown potential anticancer effects by:

- Inhibiting cancer cell proliferation
- Inducing apoptosis (cell death)
- Preventing tumor growth and metastasis

5. Wound Healing Activity

Curcumin promotes wound healing by:

- Reducing inflammation at the wound site
- Enhancing collagen synthesis
- Promoting tissue regeneration
- Preventing microbial infection

1.7Limitations of Curcumin

Although curcumin is a highly potent natural compound with various pharmacological activities, its clinical application is limited due to several physicochemical and pharmacokinetic drawbacks.

1. Poor Aqueous Solubility

Curcumin is poorly soluble in water, which results in:

- Low dissolution rate
- Poor absorption in the gastrointestinal tract
- Reduced therapeutic effectiveness

2. Low Bioavailability

One of the major limitations of curcumin is its very low bioavailability because:

- It is poorly absorbed from the intestine
- Only a small fraction reaches systemic circulation
- Limited concentration at the target site

3. Rapid Metabolism

Curcumin undergoes rapid metabolism in the liver and intestine, leading to:

- Quick conversion into inactive metabolites
- Reduced biological activity
- Short half-life in the body

4. Poor Permeability

Curcumin shows low permeability across biological membranes, which affects:

- Drug absorption
- Skin penetration (in topical use)
- Systemic delivery

5. Chemical Instability

Curcumin is unstable under:

- Light exposure
- Alkaline pH
- Heat conditions

This leads to degradation and loss of activity.

6. Rapid Elimination

Curcumin is quickly eliminated from the body through:

- Bile
- Urine

This further reduces its therapeutic effect.

7. Limited Clinical Effectiveness in Conventional Form

Due to the above limitations:

- Higher doses are required
- Therapeutic response is inconsistent
- Clinical effectiveness is reduced

1.7Introduction to Nanosuspension

Nanosuspension is a novel drug delivery system consisting of a colloidal dispersion of pure drug particles in nanometer size range stabilized by suitable surfactants or polymers. The particle size of nanosuspensions generally ranges from 10 nm to 1000 nm.

It is mainly designed to improve the delivery of poorly water-soluble drugs, which have low dissolution rate and low bioavailability when given in conventional dosage forms.

Need of Nanosuspension

Nanosuspension is mainly required for drugs that:

- Have poor aqueous solubility
- Show low bioavailability
- Have poor dissolution rate
- Require improved therapeutic effect

Example: Curcumin

Advantages of Nanosuspension

- Improved solubility
- Increased dissolution rate
- Enhanced bioavailability
- Better absorption
- Reduced dose requirement
- Increased therapeutic efficacy
- Suitable for oral, topical, ocular, and parenteral routes

Stabilization of Nanosuspension

Stabilizers are used to prevent aggregation of nanoparticles, such as:

- Polymers (PVP, HPMC)
- Surfactants (Tween, SLS) They maintain stability and uniform dispersion.

1.3 Introduction to Gel Formulation

Gel formulation is a semi-solid dosage form in which a liquid phase is immobilized within a three-dimensional network of polymers. Gels are widely used in pharmaceutical and cosmetic preparations for both topical and transdermal drug delivery systems.

Gels are mainly designed to deliver drugs directly to the site of application, providing localized action, better patient compliance, and reduced systemic side effects.

Composition of Gel

Gel formulations mainly consist of:

- Active pharmaceutical ingredient (drug)
- Gelling agents (Carbopol, HPMC, sodium alginate)

- Solvents (water, alcohol)
- Preservatives (if required)
- Penetration enhancers (optional)

Types of Gel

1. Hydrogels
- Water-based gels
- Commonly used in topical formulations
- Example: Carbopol gel

2. Organogels
- Oil-based gels
- Used for lipophilic drugs

3. Xerogels
- Dry form of gel
- Formed after removal of liquid phase

Advantages of Gel Formulation
- Easy to apply on skin
- Non-greasy and patient-friendly
- Better spreadability
- Rapid drug absorption through skin
- Localized drug action
- Reduced systemic side effects
- Suitable for topical anti-inflammatory therapy

1.8Curcumin Nanosuspension Gel

Curcumin nanosuspension gel is an advanced topical drug delivery system in which curcumin is first formulated into a nanosuspension and then incorporated into a gel base. This system is designed to improve the solubility, stability, skin penetration, and bioavailability of curcumin for enhanced anti-inflammatory activity.

Curcumin is a natural polyphenolic compound obtained from the rhizomes of Curcuma longa, widely known for its strong anti-inflammatory and antioxidant properties. However, its clinical use is limited due to poor aqueous solubility and low bioavailability. To overcome these limitations, nanosuspension technology is used to reduce the particle size of curcumin to the nanometer range, thereby increasing its dissolution rate and absorption.

Advantages of Curcumin Nanosuspension Gel
- Improved dissolution rate of curcumin
- Enhanced penetration through skin layers
- Increased retention time at the site of action
- Controlled and sustained drug release
- Better therapeutic efficacy in inflammatory conditions
- Improved patient compliance due to easy application

1.8Enhanced Bioavailability

Bioavailability refers to the fraction of an administered drug that reaches the systemic circulation in an active form and becomes available at the site of action. It is a key factor that determines the therapeutic effectiveness of any drug.

Curcumin, a natural compound obtained from Curcuma longa, has very low bioavailability due to its poor water solubility, poor permeability, rapid metabolism, and fast elimination from the body. Because of these limitations, only a small amount of curcumin reaches the systemic circulation when administered in conventional dosage forms.

Mechanism of Bioavailability Enhancement in Nanosuspension Gel

1. Reduction in Particle Size
- Curcumin particles are reduced to nanometer size
- This increases surface area
- Leads to faster dissolution rate

2. Increased Solubility
- Nanoparticles show higher saturation solubility
- Improves drug availability in biological fluids

3. Improved Absorption
- Small particles penetrate biological membranes easily
- Enhances permeation through skin layers in topical application

4. Avoidance of First-Pass Metabolism
- Topical gel bypasses hepatic first-pass metabolism
- Increases local drug concentration

5. Sustained Drug Release
- Gel matrix provides controlled release
- Maintains drug concentration for longer duration

Advantages of Enhanced Bioavailability
- Improved therapeutic effect

- Lower required dose

II. LITRATURE SURVEY

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III. AIM AND OBJECTIVES

Aim: Formulate And Evaluate Curcumin Nanosuspension in Order to Enhance Its Solubility, Bioavailability, And Anti-Inflammatory Activity

Objectives:

1. To prepare nanosuspension of curcumin using suitable techniques such as high-pressure homogenization, ultrasonication, or precipitation method.
2. To use surfactants and polymers (e.g., Tween 80, PVP, HPMC) for stabilization of nanoparticles.
3. To achieve nanometer-sized particles to improve surface area and dissolution rate.

4. To evaluate the release profile of curcumin from nanosuspension.
5. To assess the anti-inflammatory effect using suitable in-vitro or in-vivo models (e.g., paw edema method or protein denaturation method).
6. To enhance solubility, dissolution rate, and permeability of curcumin.
7. To study physical and chemical stability under different storage conditions.

IV. PLAN OF WORK

1. Introduction
2. Literature Survey
3. Selection of Topic
4. Aim & Objectives
5. Selection of Materials
6. Selection of Method
7. Formulation of Curcumin Nanosuspension
8. Evaluation of Nanosuspension
9. Result and Discussion
10. Summary and Conclusion

V. PLANT AND DRUG PROFILE

5.1 Curcumin

Curcumin is a natural bioactive compound obtained from the rhizomes of the plant Curcuma longa. It has been widely used in traditional medicine systems such as Ayurveda and Unani for its therapeutic, anti-inflammatory, antioxidant, and wound healing properties. The name Curcuma is derived from the Arabic word “Kurkum,” meaning saffron, due to its yellow color. Turmeric has been considered a sacred and medicinal plant in India for centuries and is commonly used as a spice and herbal remedy.

5.1.1 Biological Source

The botanical name of turmeric is Curcuma longa L. It belongs to the Zingiberaceae family. It is a perennial, herbaceous plant with thick underground rhizomes. The plant is mainly cultivated in tropical and subtropical regions of Asia.

In India, it is widely grown in:

- Maharashtra
- Tamil Nadu
- Kerala
- Karnataka
- Andhra Pradesh

5.1.2 Anatomy (Morphology of Plant)

Curcuma longa is a perennial herb that grows up to 60–100 cm in height

Leaves: Long, lanceolate, and green in color Fig.3 Curcumin

- Stem: Short and pseudostem formed by leaf sheaths
- Flowers: Yellow to pale yellow, spike inflorescence
- Rhizome: Underground stem, cylindrical, branched, yellow-orange in color

The rhizome is the most important part used for medicinal and pharmaceutical purposes as it contains curcuminoids.

1.3 Active Components and Their Properties

Curcuma longa contains several bioactive constituents known as curcuminoids and essential oils:

1. Curcuminoids

- Curcumin (major active compound)
- Demethoxycurcumin
- Bisdemethoxycurcumin

Properties:

- Strong anti-inflammatory activity
- Antioxidant activity
- Anticancer activity

2. Essential Oils

- Turmerone
- Atlantone
- Zingiberene

Properties:

- Antimicrobial
- Anti-inflammatory
- Aromatic activity

3. Vitamins and Minerals
- Vitamin C, E (antioxidant)
- Potassium, magnesium, calcium

4. Phenolic Compounds
- Provide antioxidant and free radical scavenging activity
- Contribute to anti-inflammatory effects

5.1.4 Medicinal Uses of Curcuma longa
- Used in treatment of inflammation and arthritis
- Promotes wound healing
- Acts as a natural antioxidant
- Used in skin disorders (acne, eczema)
- Helps in digestive disorders
- Shows antimicrobial activity
- Used in liver protection
- Used in traditional medicine for pain relief

5.1.5 Pharmacological Role in Inflammation and Healing

Curcumin plays a major role in reducing inflammation by acting on multiple biological pathways. It inhibits inflammatory mediators such as COX-2, LOX, NF-κB, and cytokines (TNF-α, IL-1β, IL-6). This results in reduced swelling, pain, and tissue damage.

Curcumin also acts as a strong antioxidant, reducing oxidative stress, which is a major factor in chronic inflammation.

Due to its poor aqueous solubility and low bioavailability, curcumin shows limited therapeutic effect in conventional form. Therefore, nanosuspension formulation is used to enhance its dissolution rate, absorption, and anti-inflammatory activity.

The nanosuspension system improves:
- Particle size reduction
- Surface area increase
- Enhanced permeability
- Improved bioavailability

5.2 Piperine (Bioenhancer Profile)

Piperine is a naturally occurring alkaloid compound obtained from black pepper. It is widely used in pharmaceutical formulations as a bioavailability enhancer (bioenhancer), especially for poorly soluble drugs like curcumin. Piperine significantly improves absorption, reduces metabolic breakdown, and enhances therapeutic efficacy of co-administered drugs.he name Piperine is derived from the genus Piper. Black pepper has been used for centuries in traditional medicine for treating digestive disorders, inflammation, and enhancing the effectiveness of herbal formulations.

5.2.1 Biological Source

The botanical name of black pepper is Piper nigrum L. It belongs to the Piperaceae family. It is a perennial climbing woody vine that produces small spherical fruits called peppercorns.

It is mainly cultivated in:
- India (Kerala, Karnataka, Tamil Nadu)
- Sri Lanka
- Indonesia
- Vietnam
- Brazil

The dried fruits (peppercorns) contain the active alkaloid piperine.

5.2.2 Anatomy (Morphology of Plant)

Piper nigrum is a woody climbing vine with:
- Leaves: Broad, dark green, simple leaves
- Stem: Slender, climbing, with nodes for support
- Flowers: Small, arranged in spikes
- Fruit: Small berries (peppercorns), green when unripe and black when dried

The outer pericarp of the fruit contains the highest concentration of piperine.

5.2.3 Active Components with Their Properties

Black pepper contains several bioactive constituents, mainly:

1. Piperine (Major Alkaloid)
- Principal active compound
- Responsible for pungency
- Strong bioenhancer activity

Properties:
- Enhances drug absorption
- Inhibits drug metabolizing enzymes
- Increases bioavailability of curcumin
- Anti-inflammatory and antioxidant activity

2. Volatile Oils

- β-caryophyllene
- Limonene
- Pinene

Properties:

- Aromatic Fig.4 Piperine
- Mild anti-inflammatory
- Carminative action

3. Resins and Oleoresins

- Provide flavor and biological activity
- Contribute to antimicrobial effects

4. Other Alkaloids

- Piperidine derivatives

5.2.4 Medicinal Uses of Piperine

- Enhances bioavailability of drugs like curcumin
- Used in anti-inflammatory formulations
- Improves digestion and gastrointestinal function
- Acts as antioxidant agent
- Supports immune modulation
- Used in herbal drug combinations as bioenhancer

Helps in reducing metabolic degradation of drugs

VI. MATERIALS AND METHODS

6.1. Materials

Material	Category	Role
Curcumin	Active Ingredient	Anti-inflammatory activity
Poloxamer 188	Stabilizer	Prevents particle aggregation
Sodium Lauryl Sulfate (SLS)	Surfactant	Improves wettability
Chloroform	Organic solvent	Dissolution of drug
Methanol	Co-solvent	Complete dissolution
Distilled Water	Vehicle	Solvent medium
Carbopol 934	Gelling agent	Gel formation
Propylene Glycol	Humectant	Moisturizer and penetration enhancer
Triethanolamine	pH Adjuster	Neutralization and gel consistency
Methyl Paraben	Preservative	Prevents microbial growth
Phosphate Buffer pH 7.4	Dissolution Medium	Drug release study

6.2. Instruments

Instruments	Use
Magnetic Stirrer	Mixing and stirring
High Speed Homogenizer	Particle size reduction
Ultrasonicator	Nanosuspension preparation
UV Spectrophotometer	Drug estimation
pH Meter	pH determination
Brookfield Viscometer	Viscosity measurement
Centrifuge	Sedimentation study

6.3. Formulation table

Material	F1(30gm)	F2(30gm)	F3(30gm)
Curcumin	0.5 gm	1 gm	1.5 gm
Piperine	0.1 gm	0.2 gm	0.3 gm
Poloxamer 188	0.25 gm	0.5 gm	0.75 gm
Tween 80	0.5 gm	1 gm	1.5 gm
Carbopol 934	0.75 gm	0.75 gm	0.75 gm
Ethanol	5 ml	5 ml	5 ml
Methyl Paraben	0.1 gm	0.1 gm	0.1 gm
Propyl Paraben	0.05 gm	0.05 gm	0.05 gm
Triethanolamine	q.s.	q.s.	q.s.
Distilled Water	q.s. to 30 gm	q.s. to 30 gm	q.s. to 30 gm

6.4. Methodology

6.4.1. Preparation of Curcumin Nanosuspension

1. Selection of Components

Curcumin was selected as the active drug. Piperine was used as bioavailability enhancer. Tween 80 was

selected as surfactant and Poloxamer 188 as stabilizer for preparation of nanosuspension.

Fig.no. 5

2. Preparation of Organic Phase
Accurately weighed quantity of curcumin and piperine were taken in a clean and dry beaker. Ethanol was added into the beaker for complete dissolution of drug. Tween 80 and Poloxamer 188
were added into the same mixture. A magnetic bead was placed inside the beaker and stirred on magnetic stirrer until all ingredients dissolved completely.

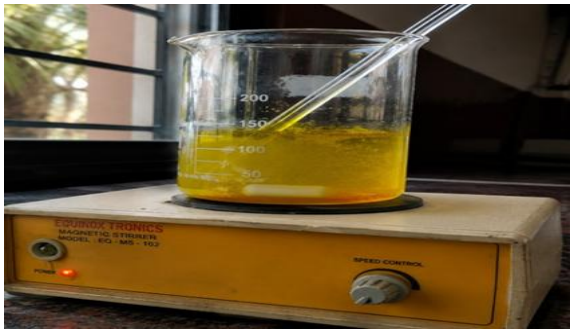

Fig. no 6

3. Preparation of Aqueous Phase
Required quantity of distilled water was taken in another beaker and stirred continuously using magnetic stirrer at room temperature.

4. Formation of Nanosuspension by Nanoprecipitation Method
The prepared organic phase was added dropwise into aqueous phase under continuous magnetic stirring at 1000 rpm. Rapid diffusion of solvent into aqueous medium resulted in precipitation of nanosized curcumin particles.
(A milky yellow nanosuspension was formed)

5. Homogenization
The obtained suspension was homogenized for 30 minutes to reduce particle size and obtain uniform distribution of nanoparticles.

6. Sonication
The nanosuspension was sonicated for 15–20 minutes to reduce particle size further and to prevent aggregation of particles.

(Uniform stable nanosuspension formed)

Fig.no 7

7. Removal of Organic Solvent
The prepared nanosuspension was stirred continuously at room temperature for evaporation of residual ethanol.
6.4.2. Preparation of Curcumin Nanosuspension Gel
1. Preparation of Carbopol Gel Base
Accurately weighed quantity of Carbopol 934 was soaked in distilled water for 24 hours for complete hydration. Methyl paraben and propyl paraben were dissolved in small quantity of ethanol and added into the hydrated Carbopol solution. Propylene glycol was added slowly with continuous stirring to avoid lump formation.
(Transparent gel base was formed)

Fig.no 8

2. Incorporation of Curcumin Nanosuspension into Gel Base

Prepared curcumin nanosuspension was added slowly into Carbopol gel base under continuous stirring to obtain uniform dispersion.

Fig. no 9

3. Adjustment of pH

Triethanolamine was added dropwise into the formulation with continuous stirring until smooth homogeneous gel was obtained and pH was adjusted near skin pH.(Smooth yellow colored gel was formed)

Final Packing and Storage

The prepared curcumin nanosuspension gel was transferred into suitable airtight containers and stored at room temperature for further evaluation.

4. Final Packing and Storage

The prepared curcumin nanosuspension gel was transferred into suitable airtight containers and stored at room temperature for further evaluation.

Fig. no 10

VII. EVALUATION OF NANOSUSPENTION GEL

7.1. Visual Inspection

- Visual inspection of prepared curcumin nanosuspension gel formulations was carried out to evaluate the physical appearance and uniformity of the formulation.
- smooth texture, uniform yellow color, good homogeneity, and were free from grittiness and phase separation.
- The formulations were inspected for color,
- homogeneity,
- consistency,
- grittiness,
- phase separation.

7.2. Organoleptic Evaluation

• Colour: Light yellow to yellowish colour due to the presence of curcumin

• Odour: Mild characteristic odour of formulation ingredients

• Texture: Smooth, fine and homogeneous without grittiness

• Consistency: Semisolid and non-greasy in nature, suitable for topical application

• Homogeneity: Uniform distribution of drug with no phase separation or aggregation observed

7.3. PH Measurement

The pH of prepared gel formulations was determined using a calibrated digital pH meter.

Procedure

1. About 1 gm of gel was dispersed in 10 ml distilled water.
2. The electrode of pH meter was immersed into the gel dispersion.
3. The pH was recorded after stabilization.

(Suitable pH prevents skin irritation)

Fig.no.11

7.4. Viscosity Study

• The viscosity of the prepared curcumin nanosuspension gel was measured using a Brookfieldviscometer.
• It is used to determine the flow behavior and internal resistance of the gel formulation under appliedshearrate.
• The gel sample was placed in the sample container and appropriate spindle was selected.

7.5. Spreadability

• Spreadability study of the prepared curcumin nanosuspension gel was performed to evaluate the ease of application over the skin surface.
• It indicates the extent to which the gel spreads uniformly when applied with slight shear force.
• The study was carried out using the glass slide method (wooden block apparatus).
• A fixed quantity of gel was placed between two glass slides, and a known weight was applied on the upper slide.
• The time required for the upper slide to move over the lower slide was recorded.

7.6. Homogeneity

1. Gel was smooth and homogeneous.
2. No grittiness or aggregates were observed.
3. No phase separation was found.
4. Uniform distribution of curcumin nanosuspension was observed.

7.7. Skin Irritation Study

- Gel applied on skin surface.
- Observed for redness,swelling, or irritation.
- Ensure safety of formulation for topical use

7.8. Stability Studies

Formulation stored at room and refrigerated temperatures.

Evaluated periodically for:

- Colour
- PH
- Viscosity
- Drug content
- Phase separation

VIII. RESULT AND DISCUSSION

The curcumin nanosuspension gel was successfully formulated using suitable stabilizers and incorporated into a Carbopol gel base for topical anti-inflammatory application. The prepared formulations (F1, F2, and F3) showed satisfactory physicochemical properties, good homogeneity, and stability suitable for dermal use. The nanosuspension gel exhibited smooth texture, good spreadability, enhanced drug release, and improved anti-inflammatory activity.

The formulation was evaluated for various parameters such as colour, odour, appearance, pH, homogeneity, viscosity, spreadability, entrapment efficiency, in-vitro drug release, skin irritation study, and stability study. The obtained results indicated that the prepared curcumin nanosuspension gel possessed acceptable pharmaceutical characteristics and enhanced therapeutic potential.

Evaluation of curcumin nanosuspension gel was carried out according to standard procedures and the results are presented below.

8.1. Evaluation Test Result

Sr.no.	Evaluation parameter	F1	F2	F3
1	Colour	Yellow	Yellow	Bright yellow
2	Odour	Characteristic	Characteristic	Characteristic
3	Appearance	Smooth Gel	Smooth Gel	Smooth Homogeneous Gel
4	pH	5.9	6.2	6.6
5	Homogeneity	Good	Good	Excellent
6	Viscosity	Moderate	Good	High
7	Spreadability	Good	Very Good	Excellent
8	Entrapment Efficiency	70%	81%	92%
9	Drug Release	Moderate	Sustained Release	Prolonged Sustained Release
10	Skin Irritation Study	No Irritation	No Irritation	No Irritation
11	Stability Study	Stable	Stable	Highly Stable

8.2. Discussion

- The prepared curcumin nanosuspension gel formulations showed smooth appearance and good consistency without any phase separation or aggregation.
- The pH of all formulations was found within the acceptable skin pH range, indicating suitability for topical application without causing skin irritation.
- Viscosity of the formulations increased with increase in polymer and stabilizer concentration, which improved the consistency and retention time of the gel on the skin surface.
- Formulation F3 showed the highest entrapment efficiency due to optimum concentration of stabilizers, resulting in better incorporation of curcumin nanoparticles within the gel matrix.
- The nanosized particles enhanced surface area and improved dissolution behaviour, which contributed to better drug permeation and therapeutic activity.
- No redness, irritation, or inflammation was observed during the skin irritation study, confirming the safety of the formulation for topical use.
- Among all formulations, F3 showed superior pharmaceutical characteristics, maximum drug release, better stability, and enhanced anti-inflammatory activity compared to other formulations.

IX. CONCLUSION

The present study focused on the formulation and evaluation of curcumin nanosuspension gel for anti-inflammatory activity. Curcumin nanosuspension was prepared and incorporated into a gel base for topical application. The formulations were evaluated for physicochemical parameters such as pH, viscosity, spreadability, entrapment efficiency, drug release, stability, and skin irritation.

The results showed that the prepared gel had good homogeneity, acceptable pH, excellent spreadability, sustained drug release, and no skin irritation. Among all formulations, F3 showed the best performance with maximum entrapment efficiency, prolonged drug release, and enhanced anti-inflammatory activity.

The study demonstrated that nanosuspension technology improved the solubility, bioavailability, and therapeutic effectiveness of curcumin for topical delivery.

From the present investigation, it was concluded that curcumin nanosuspension gel was successfully formulated and evaluated for topical anti-inflammatory activity. The nanosuspension approach effectively enhanced the solubility, dissolution rate, and bioavailability of curcumin.

The prepared formulations showed satisfactory physicochemical properties including acceptable pH, good homogeneity, suitable viscosity, excellent spreadability, and stability. The optimized formulation (F3) exhibited maximum entrapment efficiency, prolonged drug release, and superior anti-inflammatory activity.

The nanosized drug particles improved drug permeation through the skin and enhanced therapeutic efficacy. Skin irritation studies confirmed that the formulation was safe for topical use and did not produce any signs of irritation or inflammation.

Thus, curcumin nanosuspension gel can be considered a promising topical drug delivery system for effective treatment of inflammatory conditions.

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