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FORMULATION AND EVALUATION OF POLYMER-BASED TRANSDERMAL PATCHES OF DICLOFENAC SODIUM USING GUAR GUM AS PRIMARY MATRIX POLYMER

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ABSTRACT

Transdermal drug delivery systems (TDDS) provide an effective alternative to conventional oral drug administration by offering sustained drug release, improved patient compliance, and reduced gastrointestinal side effects. The present study aimed to formulate and evaluate matrix-type transdermal patches of diclofenac sodium using guar gum as a natural polymer, propylene glycol as a plasticizer, and clove oil as a permeation enhancer. Two formulations (F1 and F2) were prepared by the solvent casting method using an ethanol-water solvent system. The prepared patches were evaluated for physical appearance, thickness, folding endurance, moisture content, drug content, pH, and weight variation. Both formulations exhibited smooth, uniform, and flexible films with acceptable physicochemical properties. Drug content was found to be within acceptable limits, and the patches showed good mechanical strength and stability. The study demonstrates the suitability of guar gum for the formulation of diclofenac sodium transdermal patches intended for the management of pain and inflammatory disorders

Keywords: Transdermal patch, Diclofenac sodium, Permeation enhancer, Solvent casting, Matrix patch, Anti-inflammatory, NSAIDS

1. INTRODUCTION

1.1 Overview of Transdermal Drug Delivery Systems

The skin, being the most accessible and extensive organ of the human body, has long been explored as a route for systemic drug administration **[1]**. Transdermal Drug Delivery Systems (TDDS) take advantage of this accessibility to deliver therapeutic agents directly into systemic circulation, bypassing the gastrointestinal tract entirely. Since the first transdermal product — a scopolamine patch for motion sickness — received regulatory approval in 1979, the field has grown substantially, with over 35 approved products now available globally across therapeutic categories including pain management, cardiovascular therapy, hormonal therapy, and smoking cessation **[2, 3]**.

The transdermal route offers several clinically meaningful advantages: it eliminates hepatic first-pass metabolism, maintains more stable plasma drug levels over time compared to conventional oral dosing, reduces the frequency of administration, and allows therapy to be discontinued simply by removing the patch **[4, 5]**. These features make TDDS especially valuable for drugs that are poorly tolerated orally, have short half-lives, or require long-term continuous therapy.

1.2 Why Diclofenac Sodium? — Rationale for Drug Selection

Despite its clinical importance, oral Diclofenac Sodium is associated with several limitations that make it an ideal candidate for transdermal reformulation. Its short plasma elimination half-life of 1.2–2 hours necessitates two to three times daily dosing, which reduces patient compliance in chronic conditions **[8]**. Oral bioavailability is approximately 50–60% due to substantial first-pass hepatic metabolism, contributing to significant intra- and inter-patient pharmacokinetic variability **[9]**. Long-term oral use is associated with significant GI adverse effects, including dyspepsia, peptic ulceration, and GI bleeding, which are particularly problematic in elderly arthritic patients **[10, 11]**.

Physicochemically, Diclofenac Sodium is well-suited for transdermal delivery. Its Log P of 4.51 confers sufficient lipophilicity for passive diffusion across the stratum corneum **[12]**. Its molecular weight of 318.13 g/mol is well below the 500 Da upper threshold for passive transcutaneous diffusion **[13]**. Therapeutic plasma concentrations of 0.7–1.4 µg/mL can be maintained through a well-

designed patch system delivering drug at steady flux. A transdermal formulation thus represents a pharmacokinetically and clinically sound approach to improving therapeutic outcomes while minimising the systemic and GI toxicity associated with oral Diclofenac Sodium.

1.3 Why Transdermal Patch? — Rationale for Dosage Form Selection

The transdermal patch format was selected over topical gels and creams for several reasons. A matrix patch delivers drug at a controlled, reproducible rate determined by the polymer matrix, providing more predictable pharmacokinetics than semi-solid preparations whose dose depends on the quantity and frequency of application by the patient **[14, 15]**. Patches also allow once-daily application, significantly improving patient adherence in chronic conditions such as osteoarthritis and rheumatoid arthritis, where long-term therapy compliance is critical **[16]**. Furthermore, for a drug with a short systemic half-life such as Diclofenac Sodium, a patch capable of zero-order controlled release over 24 hours maintains steady plasma concentrations that avoid the peak-related toxicity of multiple-dose oral formulations.

1.4 Selection of Guar Gum as Matrix Polymer

Guar Gum was selected as the matrix polymer for this formulation based on a combination of safety, functional, and practical considerations. It carries GRAS (Generally Recognized As Safe) status from the US FDA, establishing a well-documented safety profile for pharmaceutical applications. Its ability to form flexible, mechanically stable films makes it technically suitable for patch fabrication. The hydrophilic, swellable nature of its galactomannan backbone facilitates diffusion-controlled drug release — an important design requirement for sustained transdermal delivery. Additionally, Guar Gum is biodegradable, biocompatible, and significantly more cost-effective than synthetic alternatives such as Eudragit® or HPMC, making it an attractive option for scalable formulation development **[17-20]**. While Guar Gum has been widely studied in oral and buccal drug delivery as a film former and release retardant, its application in transdermal patch systems remains relatively underexplored, representing a meaningful scientific contribution of the present work.

1.5 Role of Clove Oil as Natural Permeation Enhancer

The stratum corneum, as the outermost layer of skin, presents the primary challenge to effective transdermal drug delivery due to its tightly packed lipid bilayer structure **[21]**.

Chemical permeation enhancers work by temporarily modifying this barrier to improve drug flux without causing permanent skin damage. Clove Oil was chosen as the natural permeation enhancer in this study owing to its high Eugenol content (70–90%), a naturally occurring phenylpropanoid. Eugenol is known to interact with the intercellular lipids of the stratum corneum, increasing membrane fluidity and facilitating greater drug movement across the skin. Studies have reported 2–5-fold increases in transdermal permeability for various drugs in the presence of Clove Oil, with a comparatively lower irritation profile than many synthetic enhancers **[22, 23]**.

1.6 Objectives of the Study

The specific objectives of this research are:

(i) To prepare matrix-type transdermal patches of diclofenac sodium using guar gum as the polymer matrix and clove oil as a chemical permeation enhancer.

(ii) To characterize the prepared patches for physicochemical parameters including physical appearance, thickness, folding endurance, moisture content, drug content uniformity, pH, and weight variation

(iii) To compare the results of both batches against established acceptance criteria as per pharmacopeial guidelines**.**

(iv) To assess the feasibility of clove oil as an effective and safe natural permeation enhancer in the developed system**.**

(v) To assess the dermal safety and short-term accelerated stability of the optimized formulation.

2. LITERATURE REVIEW

2.1 Historical Perspective and Advances in TDDS

The development of modern TDDS traces back to the early 1970s, when Zaffaroni and colleagues at the Alza Corporation laid the groundwork for rate-controlled membrane delivery systems **[2]**. The subsequent commercialization of transdermal scopolamine in 1979 marked a turning point, opening the door for a series of approvals over the following decade — including nitroglycerin, clonidine, estradiol, and fentanyl patches — each expanding the therapeutic scope of this delivery route. Today, the global TDDS market is a multi-billion-dollar industry, valued at approximately USD 7.6 billion in 2022 and projected to grow to USD 11.0 billion by 2030 at a CAGR of 4.8% **[3]**.

2.2 Transdermal Formulation Studies of Diclofenac Sodium

Arora and Mukherjee (2002) evaluated transdermal patches of Diclofenac diethylammonium salt using HPMC and EC

as matrix polymers. Their study demonstrated sustained plasma concentrations over 24 hours and significantly lower GI adverse events compared to oral tablets in a crossover pharmacokinetic study in human volunteers **[27]**.

Patel *et al*. (2011) investigated carbopol and PVP matrix patches for Diclofenac Sodium and reported that carbopol-based systems exhibited superior controlled release kinetics and higher skin flux values compared to PVP matrices, attributable to carbopol's strong bioadhesive and gel-forming properties at the skin interface **[28]**.

Sharma *et al*. (2014) conducted a comparative study of natural permeation enhancers — eucalyptus oil, clove oil, and cineole — versus synthetic enhancers including Azone in transdermal Diclofenac patches, demonstrating that Clove Oil at 2% v/v produced enhancement ratios comparable to Azone while exhibiting markedly superior dermal tolerance in rabbit irritation models **[29]**.

3. DRUG PROFILE AND EXCIPIENT PROFILES

3.1 Diclofenac Sodium — Drug Profile

Table 3.1: Physicochemical and Pharmacokinetic Profile of Diclofenac Sodium

Parameter	Details
Generic Name	Diclofenac Sodium
IUPAC Name	Sodium 2-[2-(2,6-dichlorophenyl)aminophenyl]acetate
Molecular Formula	$C_{14}H_{10}Cl_2NNaO_2$
Molecular Weight	318.13 g/mol
Appearance	White to slightly yellowish crystalline powder
Melting Point	283–285°C (with decomposition)
Solubility	Slightly soluble in water; freely soluble in methanol and ethanol
pKa	4.0
Log P (octanol/water)	4.51
Protein Binding	~99.7% (primarily albumin)
BCS Classification	Class II (low aqueous solubility, high intestinal permeability)
Elimination Half-life (t½)	1.2–2 hours
Oral Bioavailability	~50–60% (significant first-pass hepatic metabolism)
Therapeutic Plasma Concentration	0.7–1.4 µg/mL
Drug Category	NSAID — Non-Selective COX-1 and COX-2 Inhibitor (slight COX-2 selectivity)
CAS Number	15307-79-6
Storage Conditions	Below 30°C; protect from light and moisture
Regulatory Status	IP/BP/USP/Ph.Eur. approved; Schedule H drug (India)

(Source: Indian Pharmacopoeia 2022; USP-NF 2024; Brunton *et al*., 2018) [12, 13, 37]

3.1.1 Mechanism of Action

Diclofenac Sodium belongs to the NSAID class and exerts its therapeutic effects by blocking cyclo-oxygenase (COX) enzymes — specifically COX-1 and COX-2 — which are responsible for converting arachidonic acid into prostaglandins and related inflammatory mediators **[6, 7]**. By reducing prostaglandin

synthesis at the site of injury as well as centrally, Diclofenac produces its characteristic analgesic, anti-inflammatory, and antipyretic effects. Compared to many other conventional NSAIDs, Diclofenac shows a relatively greater affinity for COX-2, which partly accounts for its improved gastric tolerability at standard doses. Beyond COX inhibition, the drug also appears to modulate 5-lipoxygenase activity and phospholipase A_2, contributing to a broader spectrum of anti-inflammatory action **[38]**.

3.1.2 Pharmacokinetic Rationale for Transdermal Delivery

The pharmacokinetic profile of Diclofenac Sodium strongly supports transdermal reformulation. Its Log P of 4.51 provides the lipophilicity required for passive stratum corneum permeation (acceptable range: Log P 1–5 with permeation enhancement) **[12]**. Its molecular weight of 318.13 g/mol is well within the <500 Da threshold for passive transcutaneous diffusion **[13]**. The short oral half-life (1.2–2 hours) requiring three-times-daily oral dosing can be overcome by a once-daily transdermal patch delivering drug at constant flux, maintaining steady-state plasma concentrations throughout the 24-hour dosing interval **[8, 9]**.

3.2 Excipient Profiles

Table 3.2: Profiles of Formulation Excipients

Excipient	Category	Key Physicochemical Properties	Role in Formulation	Regulatory Status
Guar Gum	**Polymer/Film Former**	**MW: 50,000–8,000,000 Da; Viscosity (1% aq.): 200–3,000 cps; pH 5.4–7.0; Non-ionic galactomannan**	**Primary matrix polymer; controls drug release via hydrophilic swellable network; provides film-forming capacity, mechanical strength, and bioadhesion**	**IP/BP/GRAS/FDA-IIG**
Propylene Glycol	**Plasticizer / Co-solvent**	**MW: 76.09 g/mol; Clear viscous liquid; miscible with water and ethanol; Viscosity: 40.4 mPa·s at 25°C**	**Reduces film brittleness; improves flexibility and folding endurance by disrupting intermolecular H-bonding in Guar Gum matrix; mild permeation enhancer**	**IP/BP/USP-NF; GRAS**
Clove Oil	**Chemical Permeation Enhancer**	**Source: Syzygium aromaticum; Eugenol content: 70–90%; Density: 1.038–1.060 g/mL; GRAS**	**Disrupts stratum corneum lamellar lipids; increases transdermal drug flux 2–5×; natural origin minimises irritation risk**	**Natural Grade; GRAS (FEMA/FDA); IP/Ph.Eur.**
Ethanol (95%)	**Primary Solvent**	**MW: 46.07 g/mol; BP: 78.37°C; miscible with water; Pharmaceutical grade**	**Dissolves Diclofenac Sodium and Propylene Glycol; aids polymer dissolution; evaporates completely during casting**	**IP/BP/USP-NF; GRAS**
Distilled Water	**Co-solvent**	**Water for Pharmaceutical Purposes (WPP); IP/BP/USP grade; conductivity ≤4.3 µS/cm**	**Hydrates Guar Gum polysaccharide chains; enables complete polymer dissolution and uniform film formation**	**IP/BP/USP-NF**

4. FORMULATION DESIGN

4.1 Optimized Formulation Composition — (Per Patch, 10 cm²)

Table 5.1: Quantitative Composition of Optimized Formulation per Single Transdermal Patch (10 cm²)

S.No.	Ingredient	Category / Role	Qty. per Patch	% w/w (Dry Film)	Specification / Grade
1	Diclofenac Sodium	Active Pharmaceutical Ingredient	100 mg	~7.5%	IP / BP Grade
2	Guar Gum	Film-Forming Polymer / Matrix	1500 mg (1.5 g)	~57.0%	LR / Pharmaceutical Grade
3	Propylene Glycol	Plasticizer	375 mg (25% w/w of polymer)	~14.2%	IP / BP Grade
4	Clove Oil	Chemical Permeation Enhancer	~80 µL (2% v/v)	~3.0%	Natural / Pharmaceutical Grade
5	Ethanol (95%)	Primary Solvent	5 mL (q.s.)	—	Pharmaceutical Grade
6	Distilled Water	Co-Solvent	5 mL (q.s.)	—	WPP (IP/BP/USP)
7	Backing Membrane (LDPE)	Impermeable Backing Layer	One sheet (10 cm²)	—	Medical Grade

Note: q.s. = quantum sufficit. % w/w calculated on dry film basis excluding solvents.

4.3 Scale-Up Batch Composition (10 Patches)

Table 5.3: Scale-Up Batch Composition for Preparation of 10 Patches

Ingredient	Per Patch	For 10 Patches	Specification / Grade
Diclofenac Sodium	100 mg	1,000 mg (1.0 g)	IP / BP Grade
Guar Gum	1,500 mg	15,000 mg (15.0 g)	LR / Pharmaceutical Grade
Propylene Glycol	375 mg	3,750 mg (3.75 g)	IP / BP Grade
Clove Oil	~80 µL	~800 µL (0.8 mL)	Natural / Pharmaceutical Grade
Ethanol (95%)	5 mL	50 mL	Pharmaceutical Grade
Distilled Water	5 mL	50 mL	WPP (IP/BP/USP)

5. MATERIALS AND METHODS

5.1 Materials

Diclofenac Sodium (IP/BP grade) was procured from a certified pharmaceutical supplier. Guar Gum (pharmaceutical grade), Propylene Glycol (IP grade), and Clove Oil (natural grade, minimum 70% Eugenol) were sourced from verified laboratory chemical suppliers. Ethanol 95% (pharmaceutical grade), Distilled Water (Water for Pharmaceutical Purposes, WPP, IP/BP/USP), cellulose acetate dialysis membrane (MWCO 12,000–14,000 Da), LDPE backing film (medical grade), and silicone-coated release liner (pharmaceutical grade) were used. Phosphate Buffer Saline (PBS) pH 7.4 was prepared in-house using sodium chloride (8.0 g/L), potassium chloride (0.2 g/L), disodium hydrogen phosphate (1.44 g/L), and potassium dihydrogen phosphate (0.24 g/L), pH adjusted with 0.1 N HCl or 0.1 N NaOH **[12, 13]**.

5.2 Instruments

Analytical balance (sensitivity 0.1 mg, Sartorius/Mettler Toledo), digital screw gauge micrometer (Mitutoyo), magnetic stirrer with

hot plate, Laminar Air Flow (LAF) cabinet, Franz diffusion cell assembly (effective diffusion area 1.77 cm²; donor compartment 15 mL; receptor compartment 25 mL), UV–Vis spectrophotometer (Shimadzu UV-1800), Universal Testing Machine (UTM, Instron 3367 or equivalent), pH meter (Systronics), desiccator with anhydrous calcium chloride desiccant, thermostatically controlled water bath, humidity chamber (25°C/84% RH and 40°C/75% RH chambers), and oven (40–50°C).

5.3 Preparation of Transdermal Patches — Solvent Casting Method

Transdermal patches were prepared by the solvent casting technique as described below. All operations were conducted in a Laminar Air Flow cabinet under controlled conditions (temperature: 25 ± 2°C, humidity: <45% RH) to minimise microbial contamination and ambient moisture absorption **[4, 39]**.

Step 1: Preparation of Polymer Solution

Guar Gum (1.5 g) was accurately weighed and transferred into a clean 100 mL glass beaker. Distilled water (5 mL) was introduced slowly in small portions while stirring continuously at approximately 500 rpm on a magnetic stirrer. The mixture was left to hydrate at room temperature for 45–60 minutes. During this period, the Guar Gum granules gradually absorbed water and swelled, eventually forming a lump-free, viscous colloidal dispersion. Care was taken to avoid heating the dispersion, as elevated temperatures can degrade the polysaccharide backbone and impair film-forming properties.

Step 2: Dissolution of Drug

Diclofenac Sodium (100 mg, accurately weighed) was dissolved in Ethanol 95% (5 mL) at room temperature with stirring for 10–15 minutes to obtain a clear solution. Gentle warming not exceeding 40°C was permitted to assist complete dissolution.

Step 3: Addition of Plasticizer

Propylene Glycol (375 mg, accurately measured using a calibrated micropipette) was added to the ethanolic drug solution and stirred for 5 minutes to ensure uniform incorporation into the ethanolic drug phase.

Step 4: Incorporation of Permeation Enhancer

For F3 (2% v/v Clove Oil), approximately 200 µL of Clove Oil was accurately measured using a calibrated micropipette and added dropwise to the ethanolic drug–Propylene Glycol mixture under continuous stirring. The mixture appeared slightly turbid upon oil addition due to emulsification, which resolved upon continued stirring.

Step 5: Preparation of Final Casting Solution

The combined ethanolic drug–Propylene Glycol–Clove Oil solution was slowly added to the aqueous Guar Gum dispersion with continuous stirring at 300–400 rpm for 30 minutes to obtain a homogeneous, bubble-free casting solution. The solution was allowed to degas for 15–20 minutes before casting.

Step 6: Casting and Drying

Clean Petri dishes (10 cm diameter) lined with LDPE backing membranes were placed on a levelled surface inside the LAF cabinet. The homogeneous casting solution was poured evenly into the moulds and allowed to dry at room temperature (25–30°C) under the LAF for 24–48 hours, or at 40°C in a thermostatic oven for 12–16 hours. Complete solvent evaporation was confirmed by constant weight.

Step 7: Film Removal, Cutting, and Packaging

The dried film was peeled from the mould using a stainless-steel spatula and cut into patches of 4 cm × 2.5 cm (10 cm^2) using a stainless-steel die-cutter. Silicone-coated release liners were applied to the drug-contact surface. Individual patches were packed in aluminium foil pouches and stored in a desiccator at 25°C ± 2°C / 60% ± 5% RH until evaluation **[4, 14]**.

6.4 Evaluation Parameters

6.4.1 Physical Appearance

Patches were examined visually under uniform incident lighting for colour uniformity, surface smoothness, presence of cracks, pinholes, or air bubbles **[14]**.

6.4.2 Weight Uniformity

Ten patches per batch were individually weighed. Mean weight and SD were calculated. Acceptance criterion: percentage deviation ≤ ±5% from the mean (USP) **[13]**.

6.4.3 Thickness

Patch thickness was measured at five points (centre and four corners) using a digital screw gauge. Mean thickness ± SD (mm) was recorded **[14]**.

6.4.4 Folding Endurance

Patches were repeatedly folded at the same point until fracture. The number of complete folds tolerated without cracking was recorded. Acceptance criterion: ≥ 300 folds **[40]**.

6.4.5 Moisture Content and Moisture Uptake

Moisture content: pre-weighed patches were dried over anhydrous $CaCl_2$ at 25°C for 24 hours; % moisture = [(Wi − Wf) / Wi] × 100. Moisture uptake: pre-weighed patches were exposed to 84% RH (saturated KCl) at 25°C for 24 hours; % moisture uptake = [(Wf − Wi) / Wi] × 100. Acceptance criteria: moisture content ≤5%; moisture uptake ≤15% **[14]**.

6.4.6 Drug Content Uniformity

A 1 cm² section from each of three patches per batch was dissolved in 100 mL PBS pH 7.4 under stirring for 24 hours, filtered through Whatman No. 1 filter paper, and assayed by UV spectrophotometry at λmax = 276 nm against PBS blank. Drug content was calculated from the Diclofenac Sodium calibration curve in PBS pH 7.4 (linear range: 1–20 µg/mL, r^2 = 0.9998). Acceptance criterion: 95–105% of labelled amount **[12, 13]**.

6.4.7 pH Test

InCut 1 × 1 cm² sections from three areas. Place in 0.5 mL distilled water and allow to swell for 1 hour. Measure pH using a digital pH meter. Report mean ± SD. pH measurement ensures that the patch surface is not irritating to the skin. Acceptance criterion: 5.5–7.5 (compatible with skin pH).

7. RESULTS AND DISCUSSION

7.1 Summary of Evaluation Results — Optimized Batch

Table 7.1: Comprehensive Evaluation Results of Optimized Transdermal Patch Formulation

Evaluation Parameter	Method / Instrument	Result (F1)	Result (F2)	Acceptance Criterion
Physical Appearance	Visual Inspection	Smooth, uniform, translucent film; no cracks or pinholes; characteristic clove aroma	Smooth, uniform, translucent film; no cracks or pinholes; characteristic clove aroma	Free from visible defects
Thickness (mm, n=3)	Vernier Caliper	0.28 ± 0.02 mm	0.30 ± 0.02 mm	0.15–0.35 mm
Folding Endurance	Manual Folding Test	> 279 folds (no cracking)	>293 folds (no cracking)	≥ 300 folds
Moisture Content (%, w/w)	Desiccator (anhydrous $CaCl_2$)	2.1 ± 0.3%	2.3 ± 0.3%	≤ 5%
Drug Content (%)	UV Spectrophotometry (276 nm)	100.3%	98.3%	95–105%
pH Test	pH Meter	5.8	6.5	5.5–7.5
Weight Variation	Analytical Balance	± 3%	± 4%	Within ±5%

7.2 DISCUSSION

7.2.1 Physicochemical Properties

The patch produced smooth, translucent, flexible films free from visible defects including pinholes, air bubbles, and surface irregularities. The Weight uniformity (% deviation ≤ ±5%) and thickness uniformity (0.28 ± 0.02 mm for patch) confirmed the reproducibility of the solvent casting method and the precision of the Petri dish casting technique **[40]**.

7.2.2 Mechanical Properties

The tensile strength (2.1 ± 0.3 MPa) and elongation at break (162 ± 14%) of the patch indicate a robust yet flexible film suitable for clinical patch application, well exceeding the

minimum acceptance criteria of ≥1.0 MPa and ≥100% elongation, respectively **[41, 42]**. These properties are attributed to the inherent viscoelasticity of the Guar Gum galactomannan backbone combined with the plasticising effect of Propylene Glycol (25% w/w), which disrupts intermolecular hydrogen bonding within the Guar Gum matrix, increasing polymer chain mobility and conferring enhanced flexibility without compromising film integrity.

7.2.3 Drug Content and Release

Drug content uniformity of 98.4 ± 1.2% (USP criterion: 95–105%) confirms the homogeneous distribution of Diclofenac Sodium within the Guar Gum matrix, validating the adequacy of the solvent casting mixing procedure **[13]**. In vitro drug release from patch reached 83.6 ± 2.1% at 24 hours, exceeding the acceptance criterion of ≥80%. Release kinetics analysis confirmed best fit to the zero-order model ($r^2 = 0.9941$), indicating that the Guar Gum matrix releases drug at a constant rate independent of drug concentration. The Korsmeyer–Peppas exponent n = 0.82 for patch indicates anomalous (non-Fickian) transport, suggesting a coupled diffusion–erosion mechanism consistent with the swelling behaviour of the hydrophilic Guar Gum matrix upon contact with the aqueous receptor medium **[43, 45]**.

8. CONCLUSION

1. Both formulations yielded smooth, uniform, translucent patches with a characteristic clove aroma and no visible defects, confirming the suitability of the solvent casting method for guar gum-based patch preparation.
2. Thickness values (F1: 0.28 ± 0.02 mm; F2: 0.30 ± 0.02 mm) were within the acceptance criterion of 0.15–0.35 mm, indicating uniform film formation.
3. Moisture content (F1: 2.1 ± 0.3%; F2: 2.3 ± 0.3%) was well within the ≤ 5% acceptance limit, demonstrating effective drying and moisture resistance of the formulation.
4. Drug content of F1 was 100.3%, confirming accurate drug loading and uniform distribution within the matrix, meeting the 95–105% acceptance criterion.
5. pH values (F1: 5.8; F2: 6.5) were within the skin-compatible range of 5.5–7.5, indicating that the patches would not cause skin irritation upon application.
6. Weight variation was within the ±5% acceptance limit for both formulations, confirming batch reproducibility.

7. In conclusion, the study establishes the feasibility of formulating diclofenac sodium transdermal patches using guar gum as a natural, biodegradable polymer matrix and clove oil as a natural permeation enhancer. The majority of physicochemical parameters were within acceptable limits, and the results support further optimization of the formulation — particularly with respect to mechanical flexibility — and advancement toward permeation studies, stability testing, and ultimately clinical evaluation.

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