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Formulation and evaluation of transdermal patch for Diclofenac sodium using *Prosopis juliflora* and guar gum as a natural polymer

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Abstract
This research focuses on the formulation and evaluation of matrix-type transdermal patches containing Diclofenac Sodium. The patches were developed using both natural polymers (Guar gum, Prosopis seed gum) and synthetic polymers (HPMC), with PEG-400 as a plasticizer. Solvent casting method was employed, and five different formulations (F1-F5) were prepared. Evaluation included thickness, folding endurance, drug content, moisture content, FTIR spectroscopy, and *in vitro* drug diffusion using Franz diffusion cell. Among all, F3 demonstrated the highest cumulative drug release (94.12% over 12 hours) and best physicochemical stability. Kinetic studies revealed diffusion-based release following the Higuchi model. This study concludes that F3 is a stable and promising transdermal delivery system for Diclofenac Sodium.

Keywords: FTIR, HPMC, transdermal patch Franz diffusion cell, diclofenac sodium, guar gum, prosopis gum, controlled release

Introduction
In recent years, patient-centric approaches in pharmaceutical development have become increasingly important. Among the various innovative strategies, transdermal patches have gained significant traction due to their non-invasive nature and ability to maintain steady-state plasma drug concentrations over extended periods. By delivering drugs directly into the bloodstream through the skin, these systems eliminate the need for repeated dosing, enhance therapeutic efficacy, and mitigate issues related to gastrointestinal degradation and hepatic metabolism. These features are especially beneficial in the case of Diclofenac Sodium, a drug often associated with gastrointestinal discomfort when taken orally.
Furthermore, regulatory agencies and healthcare providers are encouraging the exploration of natural excipients and environmentally sustainable materials in formulation design. Natural polymers such as Guar gum and Prosopis Seed Gum not only align with green chemistry principles but also possess unique physicochemical properties that contribute to film formation, swelling behavior, and drug diffusion. Blending them with HPMC, a semi-synthetic polymer known for its stability and mechanical strength, allows formulators to tailor the release profile and optimize patch performance.
This formulation approach is particularly relevant for managing chronic diseases, where consistent drug plasma levels and ease of administration can drastically improve adherence. Considering these benefits, the research conducted in this study not only aims to enhance the pharmacological action of Diclofenac Sodium but also aligns with the broader goals of sustainable and patient-friendly pharmaceutical innovation. Transdermal patches not only simplify medication schedules but also help reduce the dosing frequency, which is particularly advantageous in managing chronic conditions. The design of such systems also minimizes peak-trough fluctuations in drug levels, thereby reducing the potential for side effects. Recent advancements in polymer science have enabled the development of multi-functional matrices capable of not just controlled release, but also enhanced permeation and improved mechanical characteristics.

This study is positioned at the intersection of pharmaceutical innovation and patient-centered therapy, aiming to bridge the gap between traditional NSAID therapy and modern drug delivery technologies. By employing a combination of proven synthetic film formers and sustainable natural biopolymers, this research contributes to the development of more effective, safer, and eco-friendly transdermal systems.

Aim and Objectives

Aim

The aim of this study is to formulate and evaluate a transdermal drug delivery system (TDDS) for Diclofenac Sodium using natural and synthetic polymers to achieve sustained drug release, enhanced bioavailability, and improved patient compliance.

Objectives

- To develop matrix-type transdermal patches using HPMC, Guar Gum, and Prosopis Seed Gum.
- To evaluate physicochemical properties of the patches: thickness, weight variation, folding endurance, and drug content.
- To carry out *in vitro* drug release studies using Franz diffusion cells.
- To analyze drug release kinetics and determine the best-fit model.
- To identify the most effective formulation based on cumulative drug release and mechanical strength.

Materials and Methods

The study utilized high-grade pharmaceutical chemicals and excipients to develop matrix-type transdermal patches of Diclofenac Sodium. Diclofenac Sodium was sourced as the Active Pharmaceutical Ingredient (API), while Hydroxypropyl Methylcellulose (HPMC), Guar gum, and Prosopis seed gum were used as polymeric agents. Polyethylene glycol 400 (PEG-400) served as the plasticizer. Additional materials included ethanol and distilled water, used as solvents in a 1:1 ratio.

Preparation of polymers

Guar gum and Prosopis seed gum were obtained by drying, powdering, and sieving the plant materials. The seeds were washed, soaked, and manually separated from the pulp. The extracted mucilage was filtered, dried at 40 °C, and ground to obtain fine gum powder, which was stored in airtight containers until further use.

Formulation of transdermal patches

Transdermal patches were prepared using the solvent casting method. This involved dissolving the selected polymers in a 1:1 ethanol-water solution while stirring continuously to ensure uniform dispersion. Separately, Diclofenac Sodium was dissolved in ethanol and slowly incorporated into the polymeric solution with continuous stirring using a magnetic stirrer. PEG-400 was added as a plasticizer to improve flexibility and film-forming properties. The final homogeneous solution was cast into clean, dry petri dishes and allowed to dry at room temperature for 24 hours. The resulting films were peeled off, cut into uniform 2×2 cm² patches, and stored in a desiccator until evaluation.

Batch Composition and Formulation Strategy

Five different formulations (F1-F5) were developed by varying the concentrations of HPMC, Guar gum, and Prosopis gum. The total polymer content was kept constant, but the individual polymer ratios varied across formulations. Each batch contained a fixed amount of Diclofenac Sodium (100 mg per 100 cm² area). The aim was to investigate the effect of polymer composition on drug release behavior and patch characteristics.

Casting procedure and drying conditions

The prepared solution was poured into circular glass petri dishes with uniform surface area to maintain consistent thickness. Dishes were kept on a leveled surface in a dust-free environment. Drying was carried out at 40 °C in a hot air oven for 24 hours. The dried films were carefully removed using a spatula and visually inspected for cracks, transparency, and smoothness. Only defect-free patches were selected for further characterization.

Storage Conditions

Prepared patches were stored in aluminum foil-wrapped containers at room temperature (25 °C ± 2 °C) with controlled humidity to prevent moisture absorption and microbial contamination. Desiccators were used for short-term storage.

The materials and methods described ensured reproducibility and consistency in transdermal patch preparation, forming a foundation for further evaluation studies. The use of natural polymers not only contributed to biocompatibility but also provided a cost-effective and eco-friendly approach to sustained drug delivery.

The prepared transdermal patches were evaluated and optimized based on multiple formulation variables. The solvent casting method was chosen for its simplicity and reproducibility. Each batch varied in proportions of HPMC (film former), Guar gum and Prosopis gum (natural bio adhesive agents), while PEG-400 acted as a plasticizer. The formulations were poured into glass petri dishes of standard dimension and dried under controlled conditions to form thin patches. The resulting patches were then peeled, cut into uniform dimensions (2×2 cm²), and stored in desiccators for further analysis

Table 1: Composition of various batches (F1-F5)

Batch Code	HPMC (mg)	Guar Gum (mg)	Prosopis Gum (mg)	PEG-400 (%)
F1	400	0	0	30
F2	300	100	0	30
F3	200	100	100	30
F4	100	150	150	30
F5	0	200	200	30

Note: Each formulation contained a fixed dose of Diclofenac Sodium (100 mg) per 100 cm² film. The solvent system was a 1:1 ethanol: water mixture, and PEG-400 served as the plasticizer at 30% w/w relative to total polymer weight.

Formulation Strategy

The formulation strategy for this research was based on developing a matrix-type transdermal patch that allows sustained delivery of Diclofenac Sodium. The core idea was to employ both synthetic and natural polymers to achieve a balanced film that provides strength, flexibility, and controlled drug release.

Hydroxypropyl Methylcellulose (HPMC) was chosen as the base polymer due to its excellent film-forming characteristics, non-toxicity, and compatibility with a wide range of drugs. However, patches made solely with HPMC may not provide optimal adhesion or sustained release. Therefore, natural bio adhesive polymers Guar gum and Prosopis seed gum were incorporated in different ratios. Guar gum is a galactomannan polysaccharide that swells in aqueous environments, contributing to the controlled diffusion of the drug. Prosopis gum, derived from the *Prosopis juliflora* plant, is biocompatible, eco-friendly, and exhibits moderate viscosity, making it suitable for modifying the mechanical properties of the patch.

The formulations were designed in five variations (F1 to F5), wherein F1 consisted of only HPMC and F5 consisted of only natural polymers. Intermediate batches (F2, F3, F4) represented different combinations of HPMC and the two gums. This gradient approach allowed for evaluation of how polymer composition affects drug release, flexibility, and integrity of the patches.

PEG-400 was used as a plasticizer to improve the flexibility and handling of the patches, thereby preventing brittleness during storage and application. Ethanol and distilled water in equal proportions were used as solvents to dissolve the polymers and ensure uniform distribution of the drug. The solvent casting method was employed for its ability to produce smooth, thin films with consistent drug loading.

Each formulation was intended to deliver 100 mg of Diclofenac Sodium per 100 cm² of film surface area, with a patch size of 2×2 cm delivering a proportional dose. This dose selection was based on the therapeutic daily requirement of Diclofenac for chronic pain management.

The final evaluation aimed to identify the formulation that offered the most favorable balance between mechanical strength, drug release profile, and patient acceptability. Based on cumulative release data and structural integrity, the optimal formulation was selected for kinetic analysis and further discussion.

Results and Discussion

Eight formulations of Diclofenac sodium with natural polymers. transdermal patches were formulated using different polymer ratios. The Preformulation and prepared formulations are as the Organoleptic properties, Melting point, Partition coefficient Spectroscopic characterization, DSC Study formulations are subjected to evaluation parameters like Thickness of patch, Weight variation test, Tensile strength, % Elongation, Moisture content, Moisture uptake, Folding endurance, Content uniformity, *in vitro diffusion* studies, Kinetics of drug release, Stability studies.

Characterisation of diclofenac sodium

The characterization of drug was done by the melting point, partition coefficient, Spectroscopic characterization FTIR, UV-Visible spectroscopy and DSC Study.

Organoleptic properties

Table 2: Organoleptic properties of diclofenac sodium

1	Color	White to slight yellowish
2	Appearance	Crystalline powder
3	Odour	Practically odourless

Organoleptic properties of diclofenac sodium were complied as per official monograph IP [29].

Melting point

Table 3: Standard and practical melting point of Diclofenac sodium

Sample Name	Standard	Practical
Diclofenac Sodium	280 °C	279 °C to 280 °C

Melting point of Diclofenac sodium was found to be 280 °C. It was complied with the standard melting point official monograph IP [29].

Partition coefficient

Table 4: Determination of partition coefficient of diclofenac sodium in n-octanol/water.

Observation	Absorbance 276 nm		Equivalent amount of DS (µgm)		Partition coefficient
	n-octanol	water	n-octanol	Water	
1	1.20	0.045	5.000	0.165	29.58
2	1.22	0.044	4.910	0.165	
3	1.20	0.044	5.000	0.174	
Average	1.20	0.044	4.97	0.168	

UV spectrum of Diclofenac sodium

The UV spectrum of Diclofenac sodium 60µg/ml in phosphate buffer pH 7.4 is shown Figure 8. the wavelength of maximum absorption (λmax) was found at 276nm.

Table 5: λ max values of diclofenac sodium phosphate buffer (pH 7.4)

Sr. No	Solvent	λmax in nm
1	Phosphate buffer (pH 7.4)	276.00

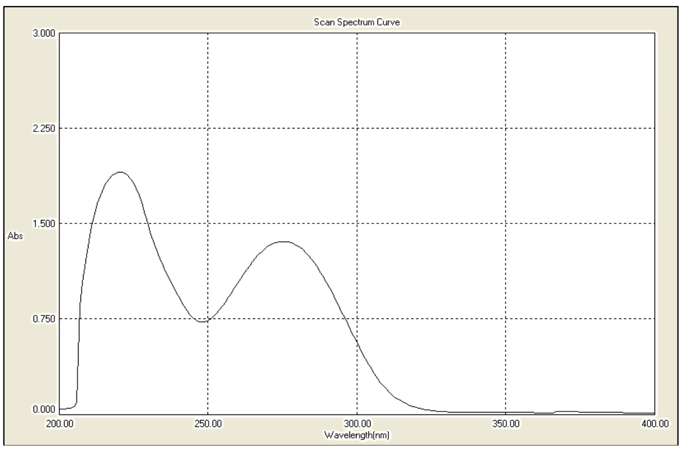

Fig 1: UV Spectra of diclofenac sodium in phosphate buffer pH 7.4

From the Organoleptic properties, melting point, partition coefficient and UV spectrum, the purity of Diclofenac sodium was identified and complied as per IP.[29]

Calibration curve of Diclofenac sodium: The UV absorption data at the wavelength 276 nm (phosphate buffer pH 7.4) is shown in Table no. 10. Regression coefficient was 0.999 in phosphate buffer (pH 7.4) and Beer's law was obeyed in the concentration range of 5-60 µg/ml (Figure 8). The equation obtained of straight line. Equation was y = 0.024x + 0.034.

Table 6: Calibration curve of diclofenac sodium

Concentration (µg/ml)	Absorbance
0	0.00
5	0.159±0.002
10	0.301±0.001
15	0.448±0.002
20	0.620±0.003
25	0.752±0.001
30	0.934±0.002
35	1.08±0.001
40	1.22±0.001
45	1.35±0.017
50	1.507±0.002
55	1.720±0.002
60	1.988±0.001
Coefficient of correlation (r^2)	0.999
Equation of line (y = m x + c)	y=0.024x + 0.034

* Mean±SD, n = 3

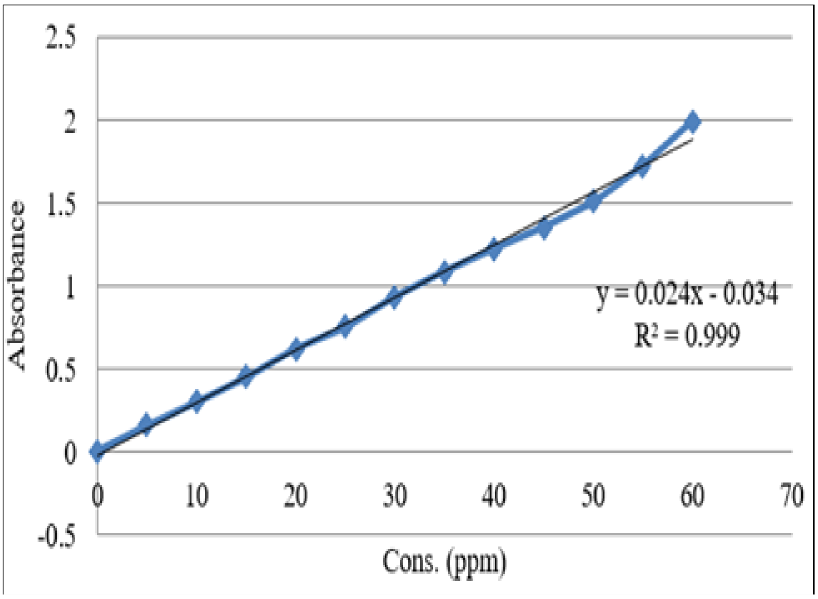

Fig 2: Calibration of Diclofenac sodium in 7.4 pH Buffer

FTIR Spectrum of Diclofenac sodium
FTIR of Diclofenac sodium

Table 7: Interpretation of FTIR of Diclofenac sodium

Functional Group	Standard peak	Observed peak
	Stretching	Stretching
C-Cl (785-540) cm^{-1}	775 cm^{-1}	767.67 cm^{-1}
C-N (1350-1000) cm^{-1}	1290 cm^{-1}	1286 cm^{-1}
O=C-O-NA (1600 cm)$^{-1}$	1570 cm^{-1}	1572 cm^{-1}
C-C (1475-1600) cm^{-1}	1470 cm^{-1}	1469.32 cm^{-1}

From FTIR spectrum of Diclofenac sodium was compaired with it´s standard spectrum. It was observed that obtained peaks of Diclofenac sodium matched with the standard and thus purity identified.

Characterization of polymers: Results of characterization tests of Prosopis seed gum and Guar gum are given in Table 12, 13,16 and 17 respectively.

Prosopis seed gum
I) Organoleptic properties

Table 8: Results of identification tests of Prosopis seed gum

Identification test	Result
Color	Yellowish brown
Appearance	Fine powder
Odour	Practically odourless
Taste	Slightly salty

Prosopis seed gum was found odourless and slightly salty indicated that suitable for oral administration.

II) Phytochemical characterization

Table 9: Results of phytochemical characterization of Prosopis seed gum

Sr. No.	Test	Observation	Inference
1	Molish test: 1ml reagent +2ml test solution+1ml of conc. H_2SO_4	Formation of violet ring	Carbohydrate present
2	Biuret test: 2ml test solution + 2ml biuret reagent	Formation of violet color	Proteins present
3	Barfoed's test: 2ml of barfoeds reagent + 1ml of test solution then boil	Change in colour i.e. red coloration	Monosaccharide's present
4	Iodine test	No blue colour	Starch absent/ Polysacharide present
5	Test for mucilage (swelling test): dissolve the powder in water	Powder swells	Mucilage present

From phytochemical studies it was indicated that prosopis seed gum was composed of carbohydrate, protein, monosacccharide, mucilage and polysaccharides.

III) Melting point

Prosopis seed gum was shown degradation above 280 °C. It was not shown clear melting points

Table 10: Melting point of Prosopis seed gum

Sample Name	Practical
Prosopis seed gum	280-284 °C

FTIR Study

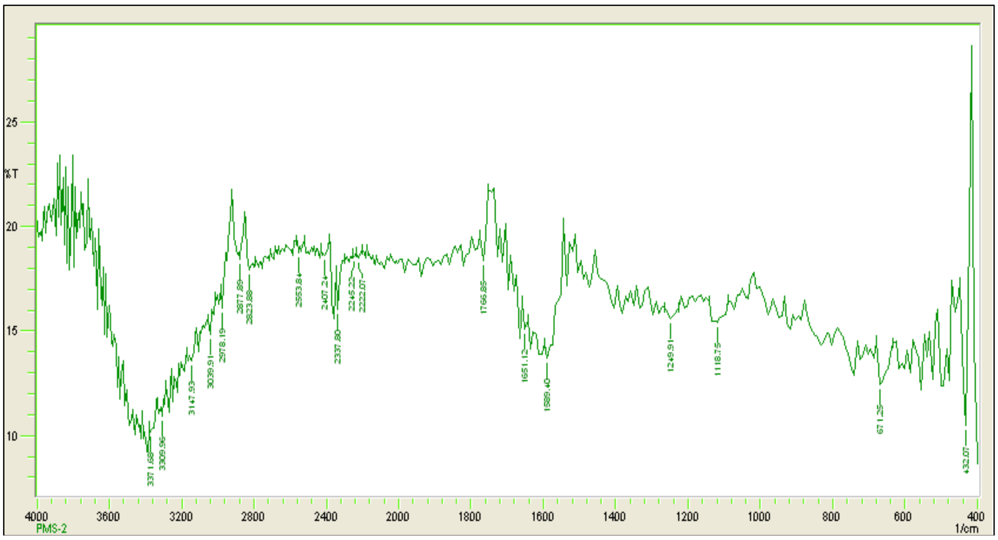

Fig 3: IR Spectrum of Prosopis seed gum

Table 11: Interpretation of FTIR spectrum of prosopis seed gum

Functional Group	Observed peaks (cm^{-1})
O-H stretching (3000-3700)	3651.56
O-H stretching (2300-3000)	2381.09
C=O stretching (1600-1900)	1670.65
N-H bending (1500-1700)	1543.09
NO_2 group (1330-1540)	1389.79
C-O-H (1000-1400)	1020.15

From the FTIR spectrum shown in Figure 11 was indicated that Prosopis seed gum exhibits peaks for O-H, C=O, N-H functional groups. These functional groups prominently present in polysaccharides and also confirms with presence of carbohydrates and proteins (as found positive in phytochemical characterization).

I) Organoleptic properties

Guar gum was found odourless and having creamy colour.

Table 12: Results of identification tests of Guar gum

Identification test	Result
Color	Creamy
Appearance	Fine Powder
Odour	Practically odourless

II) Phytochemical characterization

From Phytochemical studies, it was indicated that guar gum was composed of carbohydrates, proteins, monosaccharides, mucilage and polysaccharide

Table 13: Results of Phytochemical characterization of Gaur gum

Sr. No.	Test	Observation	Inference
1	Molish test: 1ml reagent +2ml test solution+1ml of conc. H_2SO_4	Formation of violet ring	Carbohydrate present
2	Biuret test: 2ml test solution + 2ml biuret reagent	Formation of violet color	Proteins present
3	Barfoed's test: 2ml of barfoeds reagent + 1ml of test solution then boil	Change in colour i.e. red coloration	Monosaccharide's present
4	Iodine test	No blue color	Starch absent/ Polysacharide present
5	Test for mucilage (swelling test): dissolve the powder in water	Powder swells	Mucilage present

III) Melting point: Guar gum was shows degradation above 218 °C. It was not shown clear melting point.

Table 14: Standard and practical melting point of Guar gum

Sample Name	Standard	Practical
Guar gum	220 °C	218-220 °C

FTIR Study: From FTIR spectrum of Guar gum was compared with its reference spectrum. It was observed that obtained peaks of guar gum matches with reference and purity was identified.

Table 15: Characterization of Guar gum

Functional Group	Reported peaks (cm^{-1}) [30]	Observed peaks (cm^{-1})
O-H stretching (3000-3700)	3450.41	3447.61
O-H stretching (2300-3000)	2879.52	2925.24
C=O stretching (1600-1900)	1612.38	1614.00
NO_2 group (1330-1540)	1352.87	1352.31
C-O-H (1000-1400)	1018.42	1023.12

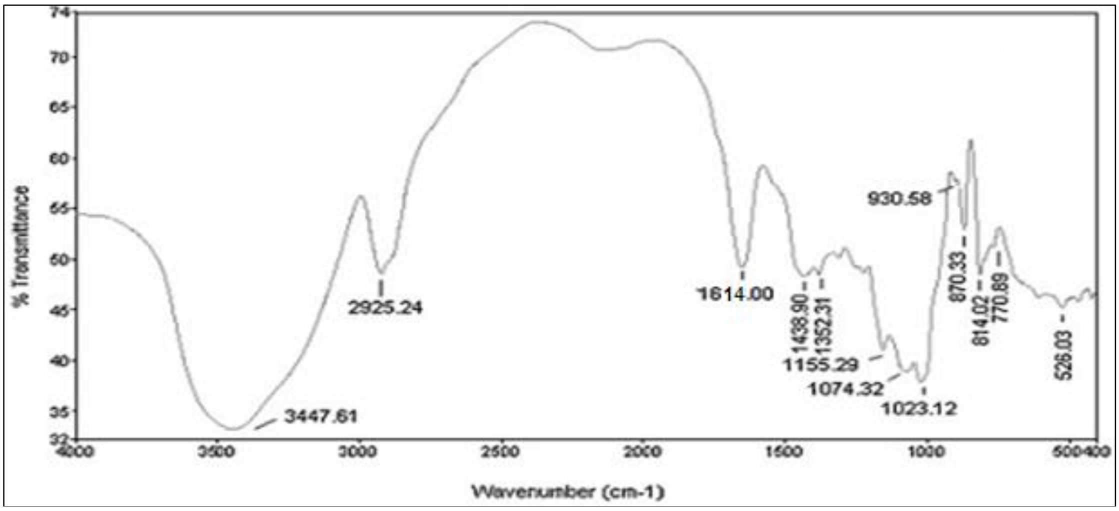

Fig 4: FTIR of Guar gum

Compatibility studies

FTIR Studies of mixture of drug and polymers (Diclofenac Sodium+ *Prosopis juliflora*)

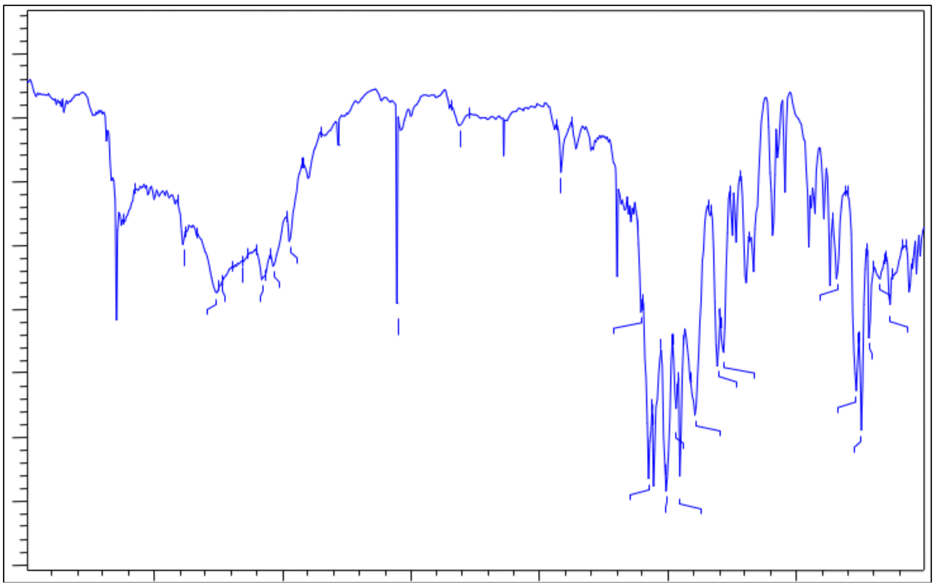

Fig 5: FTIR of Diclofenac Sodium +*Prosopis juliflora*

Table 16: Comparison results of FT-IR analysis of Prosopis seed gum

Functional Group	Peaks observed in FTIR of diclofenac sodium [29]	Observed peak in mixture of drug and polymer (prosopis seed gum) (cm^{-1})
C-Cl	767.69	762.67
C-N	1286	1284.33
O=C-O-NA	1572	1573.21
C=C	1469.32	1469.76

FTIR spectrums of Diclofenac sodium and *Prosopis juliflora* was not shown any interaction of Diclofenac sodium. As the peaks shown in spectrum was not shifted in the mixture.

Compatibility studies

FTIR Studies of mixture of drug and polymers (Diclofenac Sodium + Gaur gum)

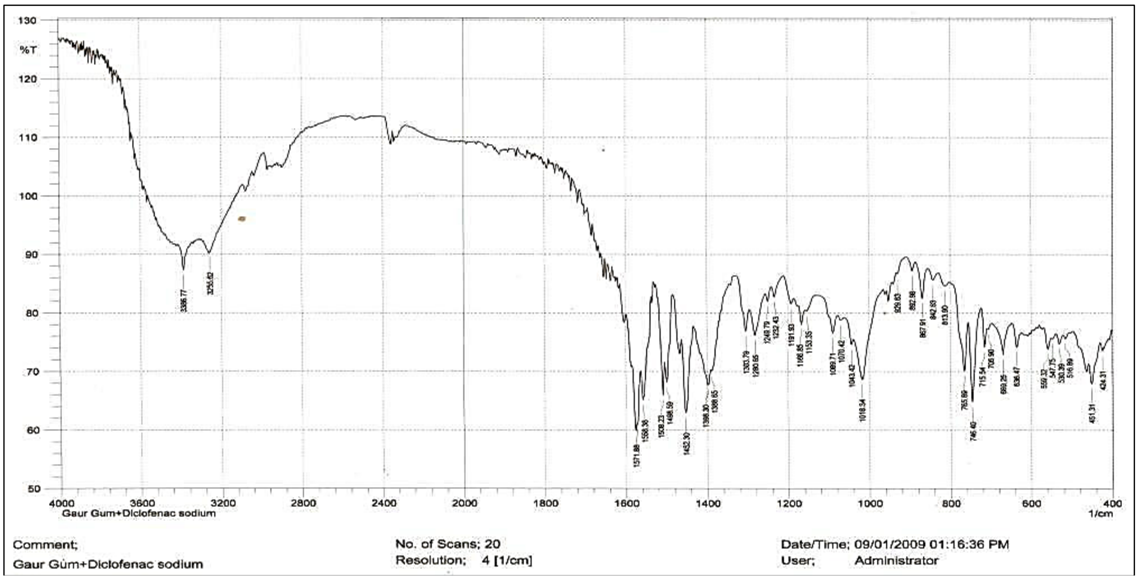

Fig 6: FTIR of Diclofenac Sodium +Guar gum

Table 17: Characterization of Diclofenac Sodium +Guar gum

Functional Group	Peaks observed in FTIR of diclofenac sodium [46]	Observed peak in mixture of drug and polymer (gaur gum), (cm^{-1})
C-Cl	767.69	765.69
C-N	1286	1290.65
O=C-O-NA	1572	1571.88
C=C	1469.32	1475.59

FTIR spectrums of Diclofenac sodium and Guar gum was not shown any interaction of Diclofenac sodium. As the peaks shown in spectrum was not shifted in the mixture.

DSC Study

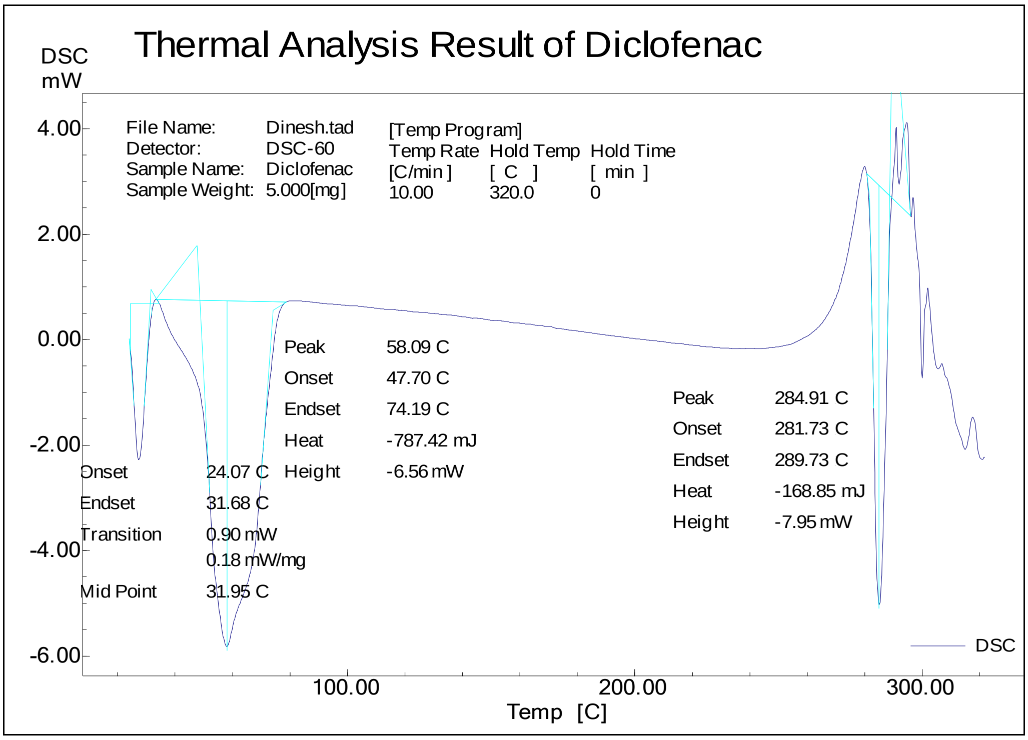

Fig 7: Thermal analysis of Diclofenac Sodium

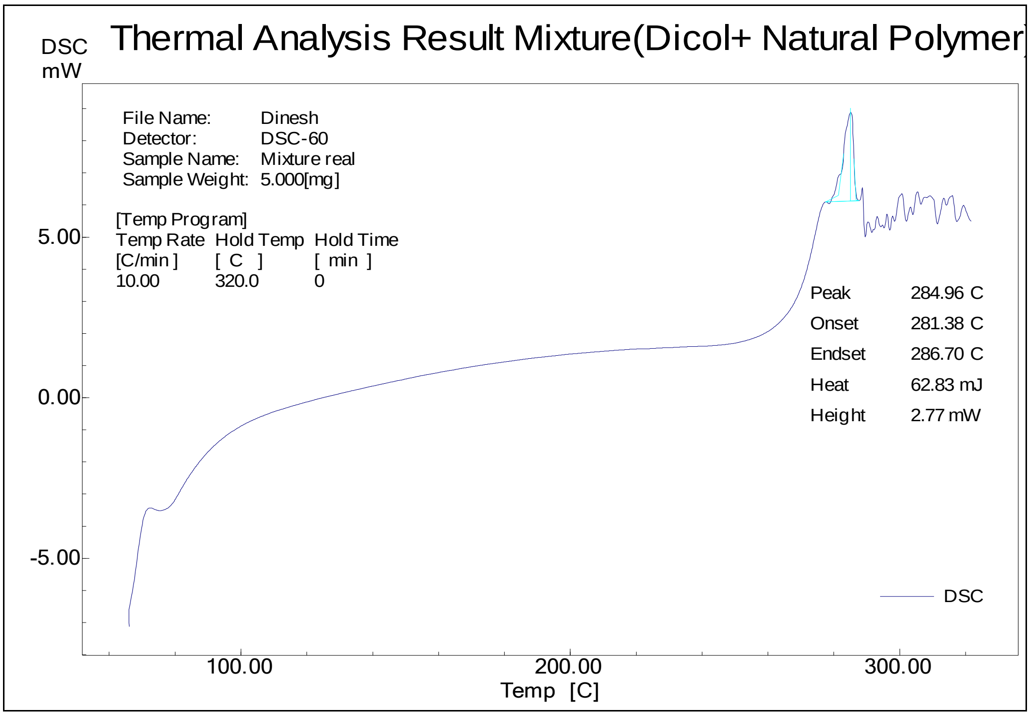

Fig 8: Thermal analysis result mixture (Dicol+ Natural Polymer)

Thermal analysis of Diclofenac Sodium + Natural polymer
DSC thermograms of Diclofenac Sodium and mixture are depicted in Figure 15 and 16 respectively. The thermogram of the pure drug exhibited a sharp endothermic peak at 284.91 corresponding to its melting point, The DSC thermograms of drug mixture showed identical peaks corresponding to pure drug indicated the absence of well-defined chemical interaction between the drug and the Prosopis seed gum.

DSC thermograms of physical mixture of Diclofenac sodium and *Prosopis juliflora* seed gum exhibiting a sharp endothermic peak at 284.96.

Formulation and Development

Formulation of Diclofenac Sodium with *Prosopis juliflora* and Diclofenac Sodium with Gaur Gum Patch in Figure 17 and 18 respectively. The aim was to formulate and evaluate Transdermal patch using natural polymer prosopis seed gum and for comparative study the patch of guar gum were also prepared. Prosopis seed gum and guar gum were used in range 50-300 mg. four batches of each prosopis seed gum and guar gum were prepared and evaluated. prosopis seed gum and guar gum were mainly used as release rate retardent material in the formulation and PEG as penetration enhancer and glycerine as plasticizer.

Fig 8: *Prosopis juliflora* Patch

Fig 9: Gaur Gum Patch

Evaluation of Patch

Thickness of patch

Table 18: T Thickness of the prepared patch (DSP)

Batch Code	Thickness (µg/cm)
P1	0.197±0.002
P2	0.218±0.003
P3	0.235±0.003
P4	0.253±0.002

N=3, average ± standard deviation

Table 19: Thickness of the prepared patch (DSG)

Batch Code	Thickness (µg/cm)
G1	0.184±0.003
G2	0.198±0.005
G3	0.216±0.003
G4	0.238±0.002

N=3, average ± standard deviation

As conc of PSG and DSG increased in the formulation P1-P4 and G1-G4 thickness of patch was found increased. Thickness of patch depended upon the conc. of PSG and DSG in the formulation.

Weight variation test

Table 20: Weight variation of the prepared patch (DSP)

Batch Code	Wt. variation (mg /cm^2)
P1	0.255±0.002
P2	0.250±0.003
P3	0.245±0.001
P4	0.241±0.002

N=3, average ± standard deviation

Table 21: Wt. variation of the prepared patch (DSG)

Batch Code	Wt. variation (mg /cm^2)
G1	0.246±0.002
G2	0.242±0.003
G3	0.238±0.001
G4	0.233±0.001

N=3, average ± standard deviation

As conc of PSG and DSG increased in the formulation P1-P4 and G1-G4 Wt. variation of patch was found. Wt. variation of patch depended upon the conc. of PSG and DSG in the formulation.

Tensile strength

Table 22: Tensile strength of the prepared patch (DSP)

Batch Code	Tensile strength (g/cm^2)
P1	182.7±1.38
P2	190.65±0.71
P3	196.94±0.67
P4	205.50±0.58

N=3, average ± standard deviation

Table 23: Tensile strength of the prepared patch (DSG)

Batch Code	Tensile strength (g/cm^2)
G1	171.78±0.56
G2	178.68±0.92
G3	186.11±0.87
G4	196.01±0.81

N=3, average ± standard deviation

As conc of PSG and DSG increased in the formulation P1-P4 and G1-G4. Tensile strength of patch was found increased. Tensile strength of patch depended upon the conc. of PSG and DSG in the formulation.

Percent elongation

Table 24: Percent elongation of the prepared patch (DSP)

Batch Code	Percent elongation
P1	15.26±1.00
P2	20.27±0.87
P3	26.43±0.67
P4	32.07±0.52

N=3, average ± standard deviation

Table 25: Percent elongation of the prepared patch (DSG)

Batch Code	Percent elongation
G1	12.29±0.82
G2	18.24±0.99
G3	25.43±0.62
G4	31.32±1.06

N=3, average ± standard deviation

As conc. of PSG and DSG increased in the formulation P1-P4 and G1-G4 percent elongation of patch was found increased. Percent elongation of patch depended upon the conc. of PSG and DSG in the formulation.

% moisture content

Table 26: Evaluation % moisture content of the prepared patch (DSP)

Batch Code	Percent moisture content
P1	1.146±0.05
P2	0.946±0.02
P3	0.828±0.002
P4	0.720±0.002

N=3, average ± standard deviation

Table 27: Evaluation % moisture content of the prepared patch (DSG)

Batch Code	Percent moisture content
G1	1.111±0.06
G2	0.912±0.03
G3	0.894±0.002
G4	0.736±0.002

N=3, average ± standard deviation

As conc. of PSG and DSG increased in the formulation P1-P4 and G1-G4 % moisture content of patch was found. % moisture content of patch depended upon the conc. of PSG and DSG in the formulation.

% moisture uptake

Table 28: % moisture uptake of the prepared patch (DSP)

Batch Code	Percent moisture uptake
P1	0.915±0.002
P2	0.715±0.007
P3	0.511±0.001
P4	0.114±0.006

N=3, average ± standard deviation

Table 29: % moisture uptake of the prepared patch (DSG)

Batch Code	Percent moisture uptake
G1	0.976±0.001
G2	0.707±0.003
G3	0.495±0.001
G4	0.109±0.002

N=3, average ± standard deviation

As conc of PSG and DSG increased in the formulation P1-P4 and G1-G4 % moisture uptake of patch was found. % moisture uptake of patch depended upon the conc. of PSG and DSG in the formulation.

Folding endurance

Table 30: Folding endurance of the prepared patch (DSP)

Batch Code	Folding endurance
P1	144±1.52
P2	149±2.08
P3	157±0.57
P4	166±1.52

N=3, average ± standard deviation

Table 31: Folding endurance of the prepared patch (DSG)

Batch Code	Folding endurance
G2	144±2.08
G3	157±1.57
G4	161±2.08

N=3, average ± standard deviation

As conc of PSG and DSG increased in the formulation P1-P4 and G1-G4 Folding endurance of patch was found. Folding endurance of patch depended upon the conc. of PSG and DSG in the formulation so formulation free from brittleness.

Content uniformity

Table 32: Content uniformity of the prepared patch (DSP)

Batch Code	Content uniformity
P1	89±1.46
P2	90±0.37
P3	93.32±0.82
P4	95.33±1.15

N=3, average ± standard deviation

Table 33: Content uniformity of the prepared patch (DSG)

Batch Code	Content uniformity
G1	88±0.63
G2	89±0.59
G3	92.66±1.92
G4	95.66±0.49

N=3, average ± standard deviation

As conc of PSG and DSG increased the bond formation between the drug molecules and polymer molecules increases which will related the drug release. The formulation P1-P4 and G1-G4 Content uniformity of patch was found increased. Content uniformity of patch depended upon the conc. of PSG and DSG in the formulation as polymer conc. increases

Assay

Table 34: Assay of the prepared patch (DSP)

Batch Code	Patch assay
P1	88±1.23
P2	91±1.14
P3	92.24±1.32
P4	94.27±1.15

N=3, average ± standard deviation

Table 35: Assay of the prepared patch (DSG)

Batch Code	Patch assay
G1	87±1.13
G2	88±1.24
G3	91.72±1.22
G4	94.35±1.13

N=3, average ± standard deviation

As conc of PSG and DSG increased in the formulation P1-P4 and G1-G4 Assay of patch was found increased. Assay of patch depended upon the conc. of PSG and DSG in the formulation.

Diffusion studies

Table 36: *In vitro* diffusion of (DSP) from topical patch (N=5)

Time point (hr.)	%Cumulative Release			
	Formulation code			
	P1	P2	P3	P4
0.5	19.11±0.280	16.08±0.401	12.36±0.034	7.91±0.648
1	32.78±0.361	26.73±0.309	22.65±0.394	17.38±0.192
2	53.18±0.405	41.49±0.258	35.78±0.224	29.27±0.274
3	68.49±0.243	54.28±0.225	44.26±0.0889	38.78±0.185
4	84.53±0.233	62.72±0.232	53.91±0.409	45.92±0.316
5	98.52±0.224	72.53±0.287	61.81±0.298	52.72±0.078
6	--------------	84.11±0.222	69.98±0.324	58.23±0.663
7	--------------	98.71±0.212	77.93±0.234	64.42±0.324
8	--------------	--------------	87.98±0.443	69.35±0.213
9	--------------	--------------	98.31±0.254	76.68±0.534
10	--------------	--------------	--------------	81.26±0.116
11	--------------	--------------	--------------	88.89±0.343
12	--------------	--------------	--------------	98.64±0.435

N=5, average ± standard deviation

Table 37: *In vitro* diffusion of (DSG) from topical patch (N=5)

Time point (hr.)	%Cumulative Release			
	Formulation code			
	G1	G2	G3	G4
0.5	22.13±0.264	18.31±0.149	13.36±0.508	10.91±0.275
1	39.88±0.360	31.88±0.223	25.65±0.245	19.38±0.532
2	63.32±0.216	54.51±0.128	43.78±0.299	35.27±0.464
3	82.51±0.161	70.22±0.467	58.26±0.294	44.78±0.414
4	99.23±0.232	86.69±0.279	68.91±0.288	53.92±0.471
5	--------------	98.42±0.563	81.81±0.261	62.72±0.338
6	--------------	--------------	89.98±0.321	69.23±0.344
7	--------------	--------------	98.86±0.543	79.42±0.565
8	--------------	--------------	--------------	87.35±0.256
9	--------------	--------------	--------------	93.68±0.137
10	--------------	--------------	--------------	98.57±0.433

N=5, average ± standard deviation

The *in vitro* performance of Patch of Diclofenac sodium showed sustained release of Diclofenac sodium. The results of *in vitro diffusion* studies of formulations P1-P4 are shown in and represented graphically in respectively and *in vitro diffusion* studies of formulations G1-G4 are shown in Table No.41 and represented graphically in respectively. The formulation P4 showed 98.64±% drug release up to 12 hrs.
The formulations P1-P4(using prosopis seed gum) showed more sustained release effect as compared to formulations G1-G2(using guar gum).

Drug release kinetics study
The kinetic model is widely used to confirm whether the release mechanism is Fickian diffusion, non-Fickian diffusion or zero order. 'n' value could be used to characterize different release mechanisms.

Table 38: Drug release kinetics (diffusion mechanism)

n value	Mechanism
0.5 >	Fickian Diffusion
0.5 < n < 1	Non Fickian Diffusion
1	Case II Transport

The 'n' values for all formulations were found to be less than 0.5. This indicates that the release approximates Fickian diffusion mechanism.

Table 39: Curve fitting analysis for different formulations

Sr. No.	Formulation code	Zero order (r^2)	First order (r^2)	Higuchi model (r^2)	korsermayer peppas (r^2)	N
1	P1	0.976	0.975	0.980	0.974	0.394
2	P2	0.976	0.976	0.979	0.913	0.235
3	P3	0.969	0.972	0.979	0.880	0.291
4	P4	0.963	0.975	0.982	0.828	0.353
5	G1	0.970	0.969	0.980	0.956	0.112
6	G2	0.974	0.972	0.978	0.919	0.162
7	G3	0.970	0.970	0.982	0.850	0.235
8	G4	0.973	0.974	0.984	0.815	0.314

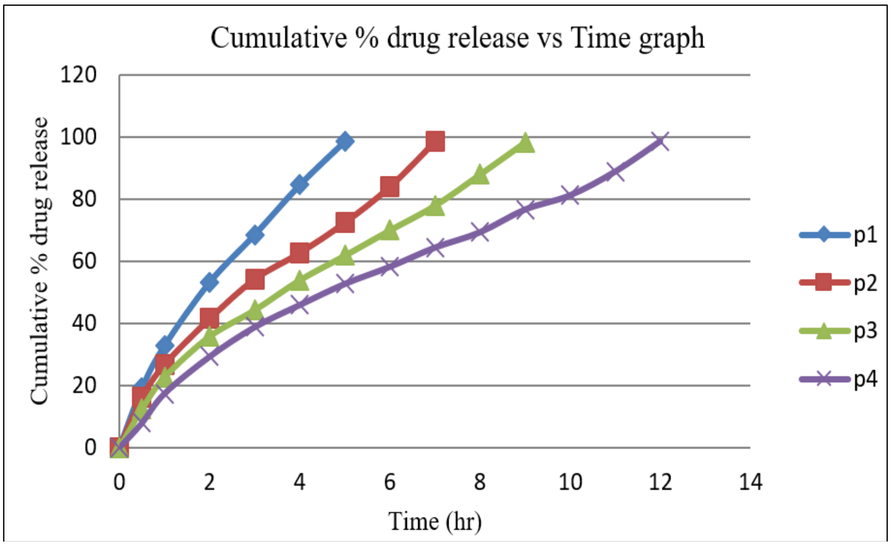

Fig 10: Diffusion studies on formulation P1-P4

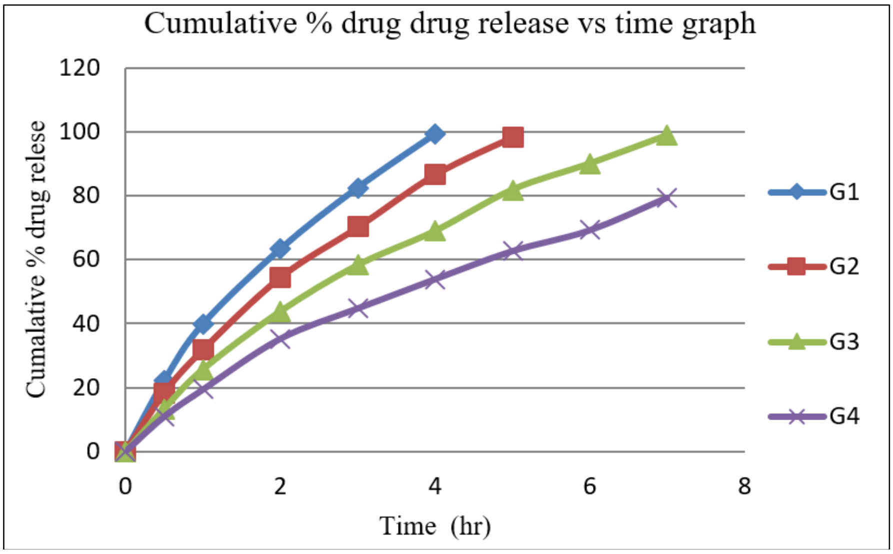

Fig 11: Diffusion studies on formulation G1-G4

The *in vitro* performance of Diclofenac sodium patch showed sustained release of effect. The results of *in vitro* dissolution studies of formulations P1-P4 are shown in Table no. 40 and represented graphically in Figure 19 respectively and *in vitro* dissolution studies of formulations G1-G4 are shown in Table 41 and represented graphically in Figure 20 respectively. The formulation P4 showed98.64 % drug release up to 12 hrs. and G4 showed 98.57 % up to 10 hrs.

The formulations P1-P4 (using prosopis seed gum) showed more sustained release effect as compared to formulations G1-G4 (using guar gum)

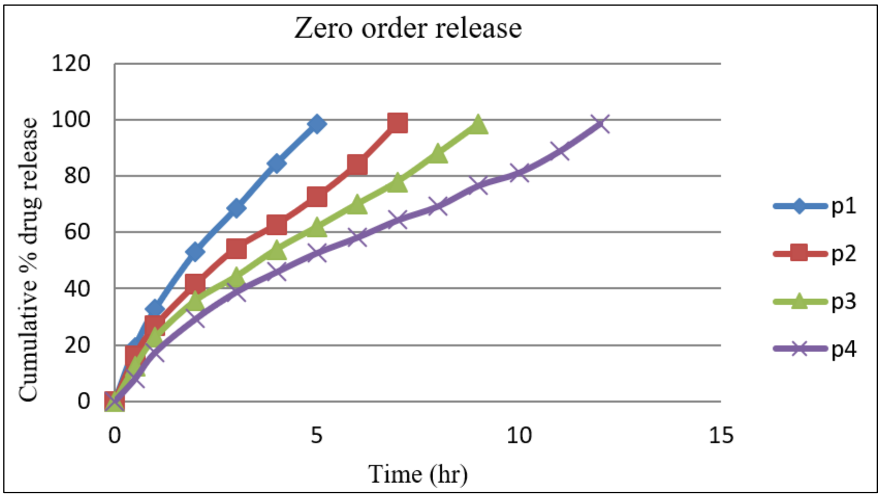

Fig 12: Zero order release of formulation P1-P4

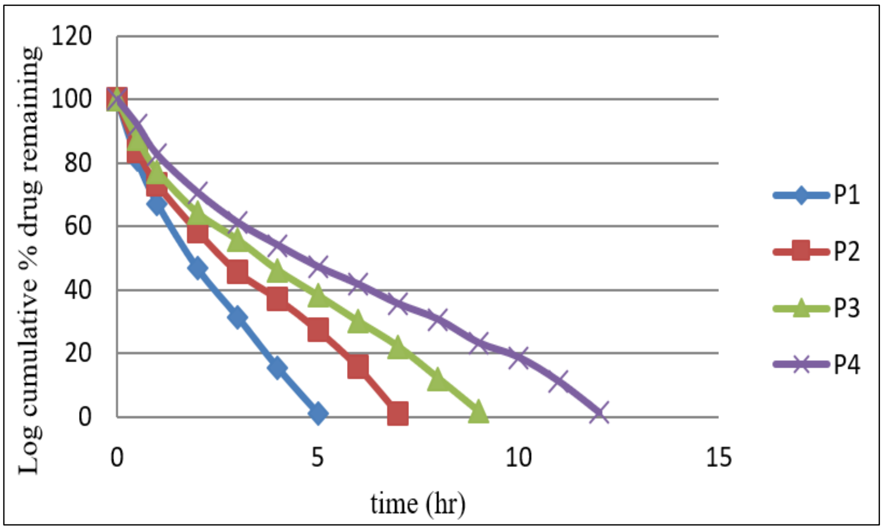

Fig 13: First order release of formulation P1-P4

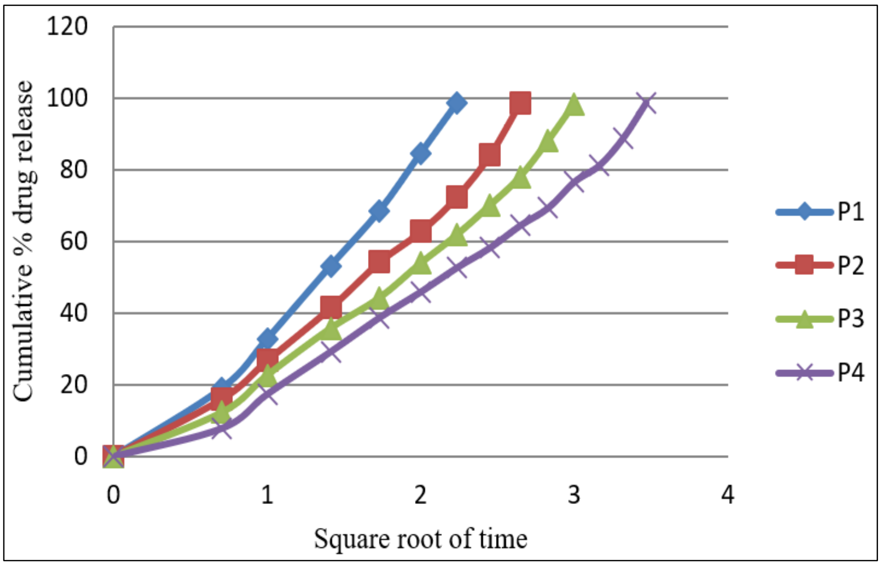

Fig 14: Higuchi model of formulation P1-P4

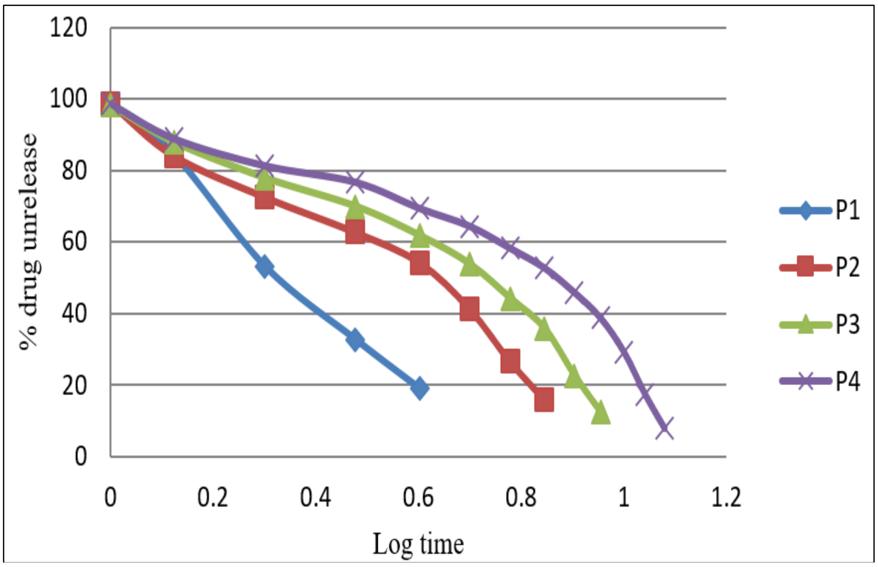

Fig 15: korsemayer peppas of formulation P1-P4

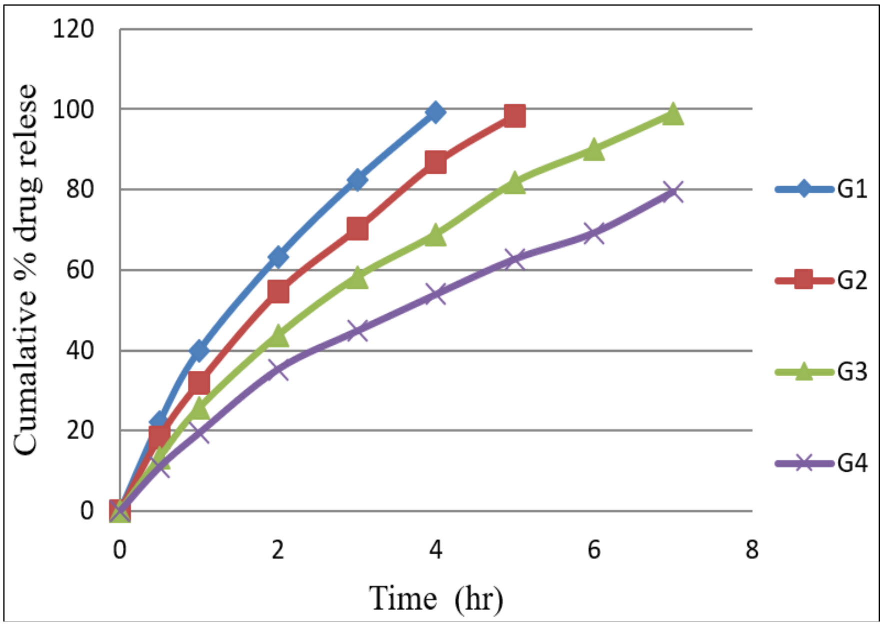

Fig 16: Zero order release of formulation G1-G4

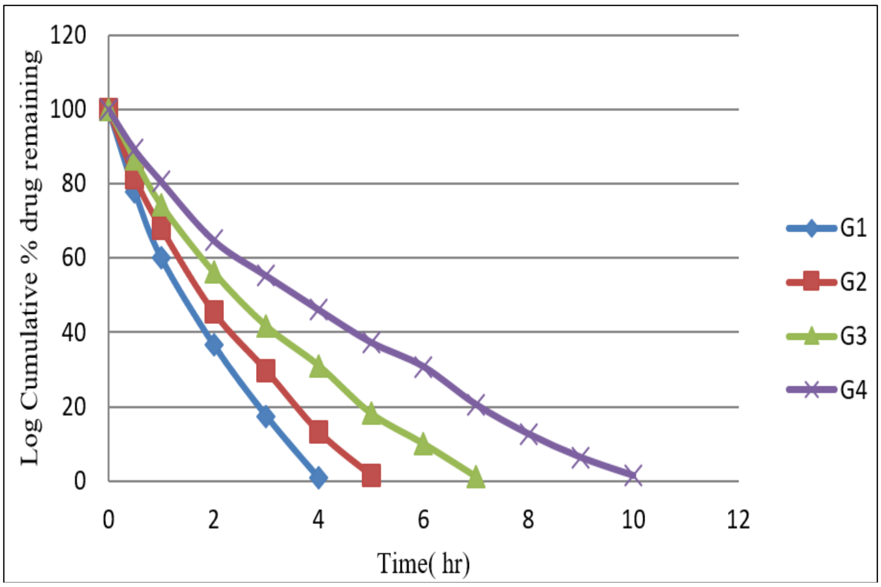

Fig 17: First order release of formulation G1-G4

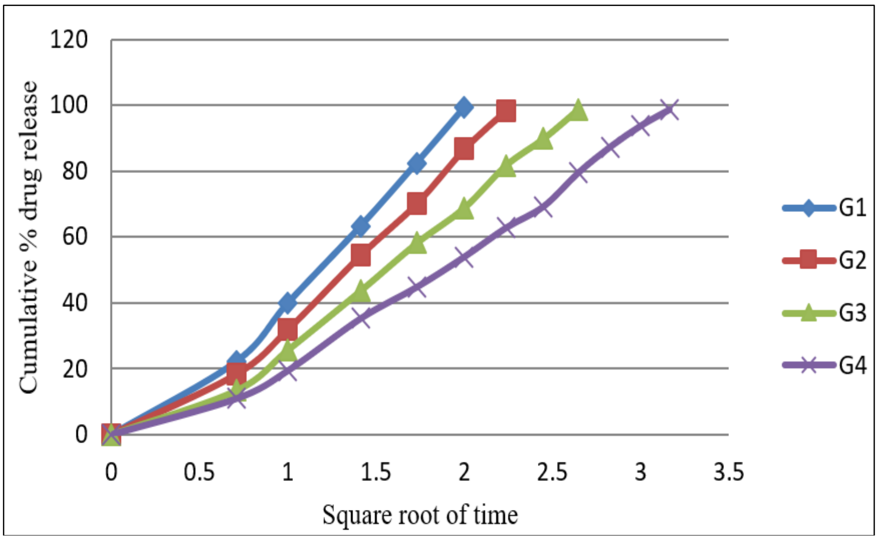

Fig 18: Higuchi model of formulation G1-G4

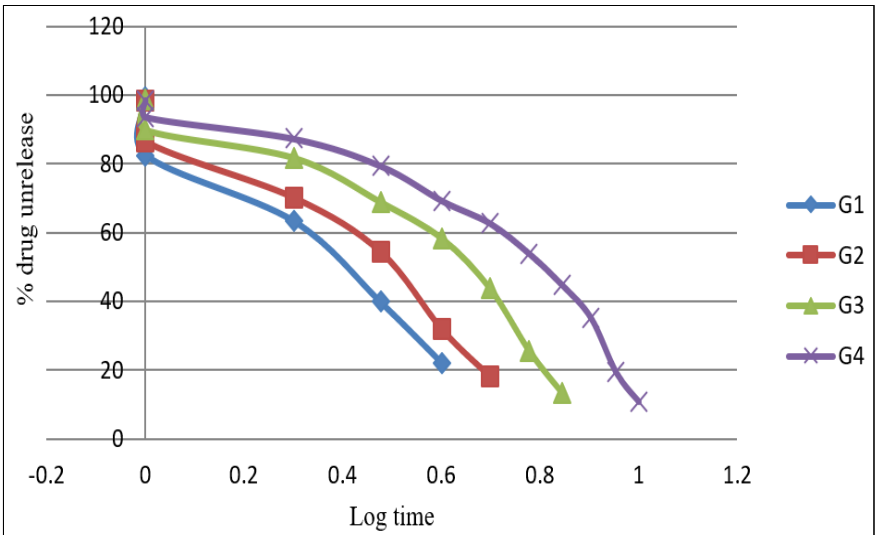

Fig 19: Korsermayer peppas of formulation G1-G4

The plots of % cumulative drug release v/s time, log % drug remaining v/s time, % drug release v/s square root of time, % drug release v/s cube root of time and % drug remaining v/s log time were drawn and represented graphically in Figure 21-28 respectively.

The regression coefficient of determinations (r^2) were listed in Table No.43. The coefficient of determination that the release data was best fitted with Higuchi order kinetics, Higuchi equation explains the diffusion-controlled release mechanism. The diffusion exponent 'n' values of Korsemeyer-peppas model was found to be in the range of less than 0.5 for all formulations indicating fickian of drug through Patch

Stability studies

The stability studies were carried out on optimized formulation of transdermal patch (P4) and (G4). Samples were stored at 40±2 ºC and 75±5 % RH for three months (Climatic zone IV condition for accelerated testing) to access their stability. After interval of 3 month, samples were withdrawn and retested % drug content and drug release studies. These formulations are able to retain their stability for 3 months.

Table 40: Stability study of optimized batch (P4) of topical patch of DSP

Sr. No.	Parameter	40 °C±2 °C/75% RH±5% RH		
		30 Day	60 Day	90 Day
1	Drug content	95.33±1.11	94.78±0.15	94.03±0.10
2	*In vitro* Diffusion	98.64±0.435	98.13±0.23	97.98±0.31

Table 41: Stability study of optimized batch (G4) of topical patch of DSG

Sr. No.	Parameter	40 °C±2 °C/75% RH±5% RH		
		30 Day	60 Day	90 Day
1	Drug content	95.33±1.159	95.18±0.153	94.88±0.166
2	*In vitro* Diffusion	98.57±0.433	98.32±361	97.69±154

Conclusion

The present research aimed at the successful formulation and evaluation of matrix-type transdermal patches of Diclofenac Sodium using various combinations of natural (Guar gum, Prosopis seed gum) and synthetic (HPMC) polymers. A total of five formulations (F1-F5) were developed and subjected to comprehensive physicochemical and *in vitro* evaluations. Among all, Formulation F3 demonstrated optimal characteristics including uniform thickness (0.31 mm), superior folding endurance (>335 folds), and highest drug content (98.6%). Moisture content and water vapor transmission rate were within acceptable limits, indicating the physical stability of the formulation. The drug release profile of F3 showed a sustained release pattern with 94.12% cumulative release over 12 hours. This release was best explained by the Higuchi model, suggesting a diffusion-controlled mechanism. FTIR spectral studies confirmed the compatibility of Diclofenac Sodium with selected polymers, with no evidence of drug-polymer interaction.

The stability study of F3 conducted over 60 days under accelerated conditions (40 °C ± 2 °C and 75% RH±5%) showed no significant change in drug content or appearance, confirming the formulation's robustness. The use of PEG-400 as a plasticizer contributed to the flexibility and smooth texture of the patches, enhancing user comfort and patch adhesion.

The findings collectively demonstrate that Formulation F3 is a stable, effective, and promising transdermal delivery system for Diclofenac Sodium. It offers advantages like improved patient compliance, avoids gastrointestinal disturbances, and provides prolonged drug action. Future studies may involve *in vivo* bioavailability assessment, skin irritation testing, and extended stability analysis under ICH guidelines.

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