



Fabrication of Transdermal Matrix Patch of Lercanidipine Hydrochloride Using Natural Polymer and Essential Oil

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The goal of the present research work was to develop and characterize a transdermal matrix patch of Lercanidipine hydrochloride (L.H.) for controlled drug delivery using the solvent evaporation method. To achieve controlled drug release, polymers such as Psyllium and HPMC K15M were optimized. Moreover, the skin permeation effect of essential oils such as linseed oil, jojoba oil, and pumpkin seed oil was investigated on Wistar rat skin. A 32 full factorial design was applied to optimize two formulation variables: concentration of essential oil as a permeation enhancer and polymer fixed-weight ratio. To study drug-excipients incompatibility, Fourier Transform Infrared Spectroscopy (FTIR) had employed, which showed the absence of chemical interaction. All formulations were evaluated for Physico-chemical parameters, ex-vivo drug release study, an *in-*

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vivo skin-irritation study on Wistar rats, and stability study. Developed matrix patch showed optimum Physico-chemical properties with the absence of skin irritation. An Ex-*vivo* drug release study revealed that both formulation variables show an effect on drug release from matrix patches. The effectiveness of the oils as the permeation enhancer was found to be in the following descending order: Pumpkin seed oil > Linseed oil > Jojoba oil. Therefore, pumpkin seed oil was selected as a permeation enhancer in the final Formulation that shows the highest flux (164.09±1.49 µg/cm²/h) and desired drug release for transdermal administration. Stability study shows that the patch was stable up to 6 months at 40±2 °C and 75±5 % R.H. and 30±2 °C and 65±5 % R.H. The present investigation demonstrates that the prepared matrix patch can deliver therapeutically effective controlled release dose of lercanidipine hydrochloride (L.H.) via transdermal route using pumpkin seed oil as the permeation enhancer.

Keywords: *Pumpkin seed oil; psyllium; hypertension; lercanidipine hydrochloride; propylene glycol; ex-vivo study; in-vivo skin irritation study.*

ABBREVIATIONS

LH : Lercanidipine hydrochloride
 PSO : Pumpkin seed oil
 LO : Linseed oil
 JO : Jojoba oil
 PG : Propylene Glycol
 CPSCA : Committee for the Purpose of Control and Supervision of Experiments on Animals
 FTIR : Fourier Transform Infrared Spectroscopy
 RH : Relative Humidity
 D.S.C. : Differential Scanning Calorimetry
 mPas : Millipascals-seconds
 mg : Milligram
 mL : Milliliter
 hrs : Hours
 wt : Weight

1. INTRODUCTION

Transdermal devices in recent time have become more popular and main concern for developing transdermal patches was to avoid hepatic first-pass metabolism and maintain plasma concentration throughout the treatment, thereby decreasing the dosing frequency and reducing gastrointestinal irritation resulting in improved patient compliance. Easy removal of the patch at any time from the target site will terminate the treatment preventing the chances of overdose and underdose and overcome the drawbacks of oral administration of selected antihypertensive drugs for the treatment of hypertension [1–4]. However, the transport of compounds via the skin is a considerable challenge due to the complex structure of the skin. Therefore, a suitable polymer matrix is required through which the drug should be released at a predetermined rate throughout the treatment [5,6]. Psyllium husk

obtained from the plant of *Plantago ovata* is rich in polysaccharide and uronic acid contents, which renders it the property of making good thin patches [7–10]. Hence, a polymeric mixture of psyllium husk and HPMC K15M was used as a controlled drug delivery component as HPMC K15M has moderate Viscosity(15000 mPas) compared with other HPMC grades [11–16]. The success of a transdermal matrix patch depends on the ability of the drug to penetrate the skin in sufficient quantities to maintain the required therapeutic levels [17,18]. Permeation enhancers are not drugs, but they are molecules that reversibly alter the barrier nature of the *Stratum corneum* and allow the drug to penetrate the skin [19]. The natural permeation enhancers available from the literature review are essential oils, terpenes, terpenoids, fatty acids, glycols, and herbal extracts [20,21]. Essential oils gained more attention from the researchers because they are compatible with a massive range of hydrophilic and lipophilic drugs along with being non-toxic, non-allergic, and clinically acceptable [22,23]. Pumpkin seed oil, Linseed oil, and Jojoba oil are well-known essential oils that have higher permeability because it contains unsaturated fatty acids, which alleviate the lipid stratum corneum by dekeratinization of corneocytes and increasing the permeation of molecules through the skin [24,25]. Propylene glycol, polyethylene glycol 400, and Dibutyl phthalate are the commonly used plasticizers. Therefore, all three here were optimized, and P.G. was selected based on folding endurance study results. Selective drug candidate, Lercanidipine hydrochloride (L.H.), is a calcium channel blocker used in the treatment of hypertension and several other cardiovascular disorders. It is administered orally with a 10 mg daily dose having 30% bioavailability, so two times are required in a day to maintain a

therapeutic level. The physicochemical properties such as high lipophilicity (Log P value 6.42 at 20- 25^o C), low molecular weight (648.19g/mol), high melting point (197-201^o C), and high pKa (9.36) at 37^o C indicates its suitability for transdermal matrix patch [23–28]. A solvent evaporation method is used for the preparation of transdermal matrix patch due to its ease of manufacturing and the possibility of achieving a higher release and flux of the lipophilic drug loaded on the matrix as suggested by the literature [29,30]. Hence, in this present research work, hydrophilic polymeric matrix patches were formulated using HPMC K15M and Psyllium along with essential oils as permeation enhancers.

2. MATERIALS AND METHODS

2.1 Materials

Lercanidipine hydrochloride (L.H.) was got as a gift sample from Glenmark generics limited, Pune, India. Psyllium was purchased from Shiv psyllium Industries, North Gujarat, India. All the investigated oils, namely Linseed oil (L.O.), Jojoba oil (J.O.), and Pumpkin seed oil (PSO) purchased from Hamdard Laboratories, Ghaziabad, India, Hydroxy Propyl Methyl Cellulose K-15M (HPMC K15M) and propylene glycol (P.G.) supplied by S.D. Fine Chemicals Ltd., Mumbai, India. All remaining chemicals and solvents were reagent grade. Double distilled water was used throughout the study.

2.2 Animals

Wistar rats (180-200g, 6-8 weeks old) were supplied by the Zydu Research center (Village Moraiya, Near Nova Petrochem, Ahmadabad, Gujarat). The experiments on animals *in-vivo* skin-irritation study and *ex-vivo* permeation study using Wistar-rat skin were performed following the guidelines given by the Animal Ethical Committee, CPCSEA.

2.3 Methods

2.3.1 Dose calculation

The dose of L.H. for the transdermal patch is calculated based on the value of targeted flux and transdermal flux. Targeted flux of LH is 166.46 $\mu\text{g}/\text{cm}^2/\text{hr}$ (calculated by equation: targeted flux $J_{ss} = C_{ss} \times Cl_t \times BW/A$, where 3.3 $\mu\text{g}/\text{l}$ and 3.37 mL/min/kg are C_{ss} and Cl_t respectively

for LH). The oral dose of L.H. is 10 mg or 20 mg once daily, and bioavailability is 40%. Therefore, an orally available dose to maintain plasma concentration is only 4 mg. To surplus the loss of drugs in different layers of skin and for getting the required flux here, a double dose is required. Therefore, in the present study dose of L.H. for the preparation of the transdermal patch having a 4-cm² area is 8mg (73 mg for a total 6.8cm Petri plate), and it gives flux 165 $\mu\text{g}/\text{hr}/\text{cm}^2$, which is very nearer to the required flux [31,32].

2.3.2 Method for preparation of transdermal matrix patch containing L.H.

The transdermal matrix patches were prepared using different ratios of Psyllium and HPMC K15 M. The polymers concentration was varied with 3%w/v, 4%w/v, and 5%w/v by keeping the constant balance (2:1) of HPMC K15M psyllium and allowed to swell for 2 hrs in water. As per dose calculation, accurately weighed the amount of L.H. dissolved in ethanol, and this drug solution was added into the polymeric solution with continuous stirring using a magnetic stirrer. Then propylene glycol and essential oil are incorporated as plasticizers and penetration enhancers, respectively. The inverted funnel was kept over the Petri plate for uniform evaporation, after complete drying biaxial oriented polyethylene, film glued as a backing membrane, and a glossy paper having smooth surface used as a release liner. The dried films were removed from the Petri plate and cut into a 4-cm² area, wrapped in aluminum foil, and stored in desiccators for further studies [31–34].

2.3.3 Preliminary trial study for the optimization of matrix patch formulation

Preliminary trial batches were prepared and evaluated for the optimization of various concentrations of polymers, drugs, plasticizers, and permeation enhancers. Formulations L1 to L3 were prepared with varying concentrations of L.H. 8mg, 10mg, and 12mg to study the effect of L.H. concentration on drug release and permeation. Batches L4 to L6 were prepared with varying concentrations of polymers with 3%w/v, 4%w/v, and 5%w/v to study the effect of thickness of polymeric matrix on drug release and permeation. Batches PE 1 to PE 7 were prepared with varying concentrations of J.O., L.O., and PSO for the optimization and selection of effective permeation enhancers. Formulations of all preliminary trial batches are displayed in [Table 1].

Table 1. Composition of Preliminary Trial Batches and Results of Dependent Variables (Cumulative Drug Release at 1 Hr(Q1), 16 Hrs (Q16), and Tensile Strength)

Batch code	LH loading g (mg)	HPMCK15M: Psyllium(2:1) (mg)	EO-Loading (%w/w total wt of polymer dry weight)	CDR at 1 hr(Q1)	CDR at 16hrs(Q1)	Tensile strength
L1	8	300	-	8.22±0.23	68.27±0.19	3.27±0.03
L2	10	300	-	10.19±0.35	73.91±0.27	4.69±0.04
L3	12	300	-	11.11±0.31	79.13±0.17	4.72±0.03
L4	8	300	-	8.22±0.23	68.27±0.19	3.27±0.03
L5	8	400	-	7.18±0.16	57.79±0.21	3.45±0.04
L6	8	500	-	6.54±0.11	50.32±0.19	4.96±0.05
PE1-control	8	300	Without EO	8.22±0.23	61.27±0.19	3.27±0.03
PE2 - LO	8	300	10% w/w	9.19±0.15	64.76±0.06	4.19±0.02
PE3 -LO	8	300	20% w/w	10.41±0.13	66.42±0.19	4.22±0.03
PE4 - JO	8	300	10% w/w	9.12±0.14	68.89±0.11	4.17±0.03
PE5 - JO	8	300	20% w/w	10.08±0.19	69.32±0.17	4.48±0.02
PE6 – PSO	8	300	10% w/w	9.94±0.18	75.11±0.21	4.56±0.03
PE7 – PSO	8	300	20% w/w	11.57±0.13	78.81±0.13	4.67±0.04

Table 2. Composition of L.H. Loading Factorial Design Batches P1 to P9

Batch code	P1	P 2	P 3	P 4	P5	P 6	P 7	P 8	P 9
Lercanidipine HCL(mg)	73	73	73	73	73	73	73	73	73
HPMC K15M(mg)	250	250	250	225	225	225	200	200	200
Psyllium(mg)	50	50	50	75	75	75	100	100	100
Water(mL)	12	12	12	12	12	12	12	12	12
Ethanol(mL)	8	8	8	8	8	8	8	8	8
Propylene glycol(%w/w of dry polymer wt)	20	20	20	20	20	20	20	20	20
Pumpkin seed oil(%w/w of dry polymer wt)	10	20	30	10	20	30	10	20	30

2.3.4 Statistical optimization of the formulation variables using experimental design approach

A preliminary trial study suggested that the concentration of polymers and permeation enhancers mainly affect the release and permeation of L.H. from the patch. Therefore, further optimization of these two formulation variables was performed using experimental designs by the fabrication of transdermal matrix patches having desired drug release and permeation flux. A 3² full factorial design, from Design Expert software 9.02 selected (A.M. Abdel Azim, et.al, 2014). This design involved three dependent variables (Y1, Y2, and Y3) and two independent variables (X1 and X2). The release response can be expressed as Y= f (X1, X2). The selected two independent variables for the present investigation were X1, polymer fixed weight ratio, and X2, essential oil concentration in the patches. All other formulation variables

were kept constant throughout the study. The dependent variables were Y1, drug release in 1st hr (Q1), Y2, drug release at 16 hrs (Q16), and Y3, the tensile strength of prepared patches. The composition of nine formulations based on this experimental design is displayed in [Table 2]. After completion of statistical optimization experiments, polynomial equations and 3-dimensional plots were generated to study the effect of X1 and X2 on Y1, Y2, and Y3, to identify the optimized L.H., loaded transdermal matrix patch. The final identified batch was fabricated and subjected to the validation of statistical optimization design [35].

2.4 Evaluation Study of Transdermal Matrix Patch Containing LH

2.4.1 FTIR study

FTIR spectroscopy was used as an analytical tool to find out compatibility between L.H., HPMC

K15M, Psyllium, PSO, L.O., J.O., and P.G. FTIR spectra of pure drug and final Formulation carried out using the K.B.R. disc method as graphs of FTIR shown in results section [32,33,36].

2.4.2 Physicochemical evaluations of LH containing transdermal matrix patch

The experimental design formulations, batches P1 to P9 evaluated for various physicochemical evaluations such as thickness, folding endurance, moisture uptake, and loss, tensile strength, and drug content according to the method given by A.M. Abdel Azim, et al. 2014 Rajesh Singh Patel and S.S. Poddar, 2009, Pichayakorn W, et al. 2013.

2.4.3 Ex-vivo skin permeation study and preparation of rat skin

Wistar rats were sacrificed with prolonged ether anesthesia, and the abdominal skin of each rat was excised. Hairs on the skin of an animal and subcutaneous tissues were removed with a sharp blade. The skin was washed with phosphate buffer saline, wrapped in aluminum foil, and stored in a deep freezer at -20°C until further use. At the time of the *ex-vivo* permeation study, the skin was brought to room temperature and hydrated in phosphate buffer solution for half an hour before the study and then placed over the receptor compartment of Franz diffusion cell with a diffusion area of 0.64 cm^2 and a receptor compartment capacity of 13 mL. The L.H. loaded transdermal matrix patch was placed over the membrane by keeping the dermal side in contact with the receptor medium. The receptor compartment is filled with 13 mL of pH 6.8 buffer. The temperature of the diffusion medium was maintained at $32 \pm 2^{\circ}\text{C}$. This whole assembly was kept on a magnetic stirrer and solution in the receiver compartment constantly and continuously stirred using a magnetic bead. Samples were withdrawn (2 mL, each time) at different time intervals and replaced with an equal amount of pH 6.8 buffer. The sample was analyzed at 357nm after suitable dilution using a U.V. spectrophotometer. The amount of drug permeated per square centimeter at each time interval was calculated and plotted against time [37–43].

The *Ex-vivo* release data were subjected to various kinetic equations to find out the release mechanism and order of drug release. Transdermal flux was calculated using the value

of the slope of the cumulative drug release curve that was constructed by the steady-state values of the cumulative amount of drug permeated (mg/cm^2) vs. time. Permeation coefficients (cm/hr) were calculated by dividing the flux with initial drug loading (mg/cm^2). Lag time calculated from back extrapolation. Diffusion coefficient (D/h^2) and permeability coefficient (K_p) also calculated from the data of *ex-vivo* studies using given equations, respectively ($D/h^2=1/6 \times T_{\text{lag}}$, $J_{\text{ss}} = (dq/dt).1/A$, $K_p = J_{\text{ss}}/C_s$). The regression analysis of steady-state data and release rate was calculated. The experiment was performed in triplicate, and the mean results were recorded [28,43–46].

2.4.4 In-vivo skin irritation study

The study was performed on Wistar rats to determine irritation after a single application of the prepared transdermal matrix patch. Accurately cut 4 cm^2 size patch applied on the clean backside skin of rat and removed after 16 hrs. The exposed skin was evaluated for the formation of edema and erythema and any type of irritation. The rats were divided into two groups of 3 rats in each group ($n=6$), one group as a control and another group as a test (prepared matrix patch). Prior permission takes from the animal ethical committee for this study [47–51].

2.4.5 Stability study

The final optimized batch is subjected to stability study to evaluate any change in appearance and drug release when exposed to accelerated conditions of the environment during storage, handling, transport, and use. The analysis was performed according to ICH guidelines at 40°C and 75% R.H. and at $30 \pm 2^{\circ}\text{C}$ and 65 \pm 5 % R.H. in a humidity chamber for six months, and it was analyzed for physicochemical parameters at particular time intervals [46,49,50].

3. RESULTS

3.1 Regression Analysis of the Optimization of Formulation

The statistical analysis of factorial design batches was performed using Design expert software 9.02. The results of the dependent variables for the factorial design batches are given in (Table 3). To evaluate the contribution of both the factors at three different levels on responses, a two-way analysis of variance

(ANOVA) was performed using design expert software 9.02. To demonstrate the influence of each factor on responses graphically, the response surface plots such as contour and 3D plots were generated using the software [47,48]. The response surface plots for dependent variables, tensile strength, % drug release in 1 hr(Q1), and % drug release in 16hrs (Q16) are shown in (Fig. 1-3), respectively. The value of $p < 0.05$ was considered to be significant.

3.2 Validation of Optimization Design

Selected criteria for independent and dependent variables for formula optimization.

3.2.1 Independent variables

X₁- Polymer fixed weight ratio of psyllium and HPMC K15M (400 mg):(50:350, 75:325, 100:300) and X₂- Pumpkin seed oil concentration – 10% w/w, 20% w/w and 30% w/w.

3.2.2 Dependent variables

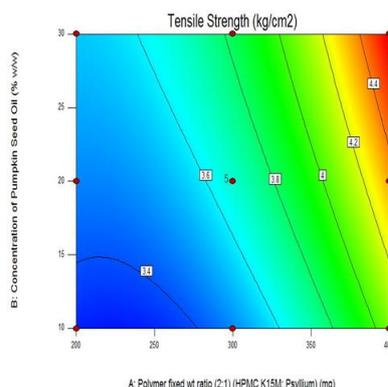
(Y₁) Tensile strength – 4 to 6 kg/ cm², (Y₂) Percent drug release in 1 h – 5 to 20 %, (Y₃) Percent drug release in 16 h – 85 to 91 %.

3.2.3 Checkpoint analysis of batches P1 to P9

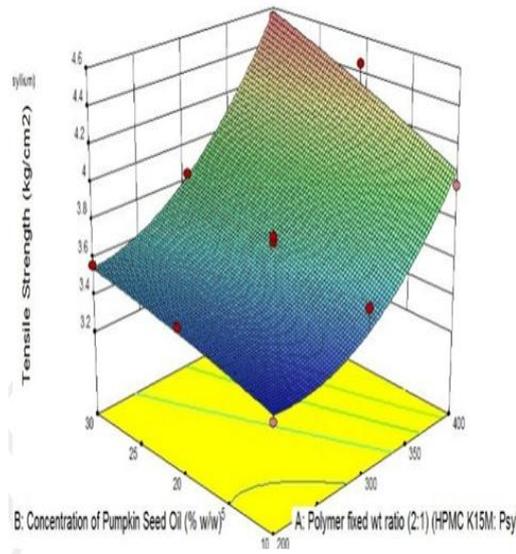
To validate the selected mathematical models, checkpoint validation analysis was performed and from the overlay plot, two sets of both the independent variables were selected, and based on that, two batches were prepared with the quantity selected from the overlay plot. The study was performed three times and obtained actual results mean values of all three dependent variables were compared with predicted values, the differences were found to be significant ($P > 0.05$). Therefore, obtained actual results revealed that the quadric model is valid for the relationship between theoretical predictions of dependent variables with the practically obtained results [35].

Table 3. Results of Dependent Variables (Cumulative Drug Release at 1 Hr(Q1), 16 Hrs (Q16), and Tensile Strength

Batch Code	Coded Value & Actual value		Dependent variables		
	Polymer fixed ratio HPMCK15M: Psyllium(2:1) (300 mg) X1	PSO (% w/w) X2	% Drug released in 1 hr (%) Y1	% Drug released in 16 hrs (%) Y2	Tensile Strength (Kg/cm ²) Y3
P1	-1	-1	11.42±0.24	73.16±0.52	3.30±0.01
P2	-1	0	12.72±0.45	75.54±0.81	3.49±0.02
P3	-1	1	13.16±0.41	77.28±0.13	3.56±0.03
P4	0	-1	14.41±0.43	80.41±0.16	3.59±0.03
P5	0	0	15.62±0.06	82.78±0.12	3.69±0.02
P6	0	1	16.24±0.31	84.36±0.16	3.84±0.02
P7	1	-1	17.22±0.16	87.64±0.06	3.99±0.03
P8	1	0	18.36±0.21	89.31±0.91	4.45±0.04
P9	1	1	19.18±0.07	87.14±0.14	4.56±0.03



(A) Counter Plot

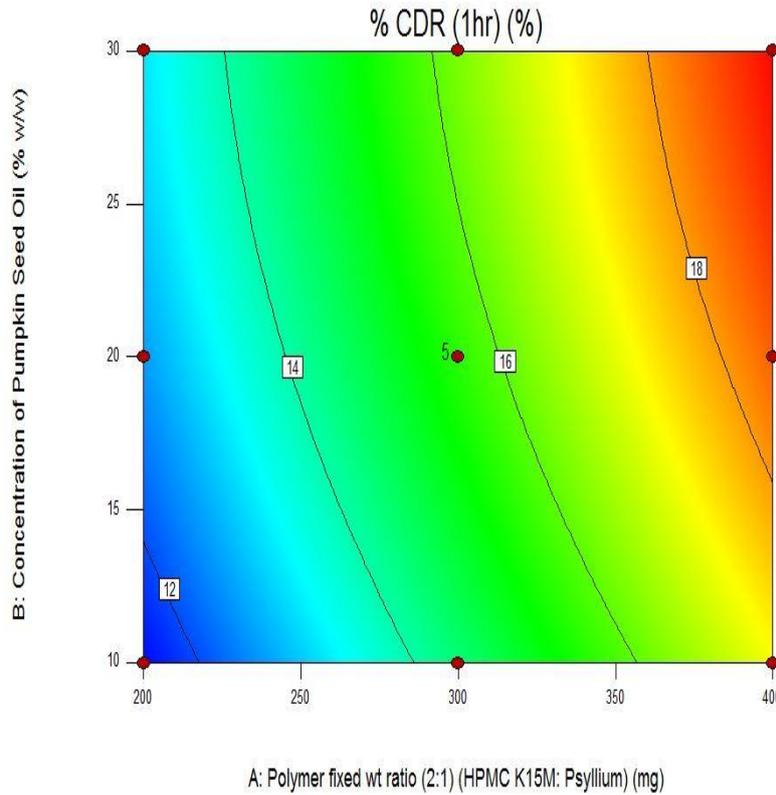


(B) Response Surface Plot

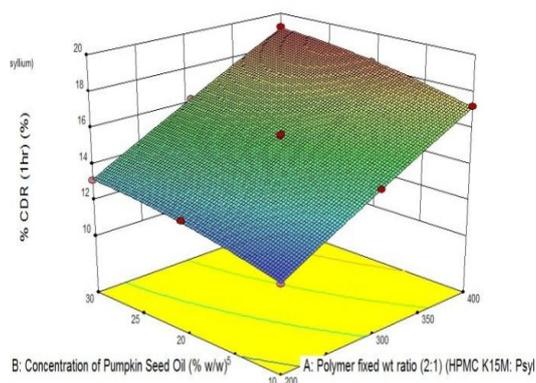
Fig. 1. (A) Counter Plot and (B) Response Surface Plot of the Effect of Polymer fixed ratio HPMCK15M: Psyllium (2:1) and Pumpkin Seed Oil on Tensile Strength

*Polynomial Equation

$$\text{Tensile Strength} = +3.67 + 0.44 \times A + 0.18 \times B + 0.075 \times AB + 0.23 \times A^2 - 0.020 \times B^2$$



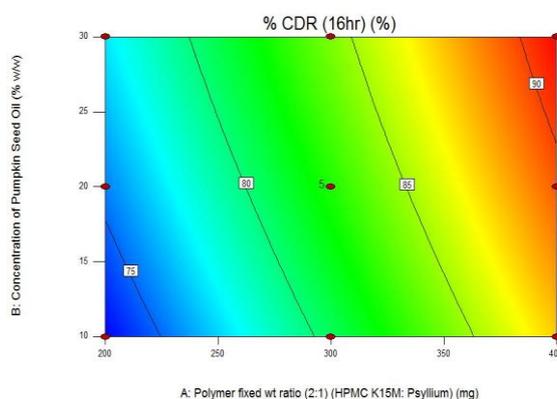
(A) Counter Plot



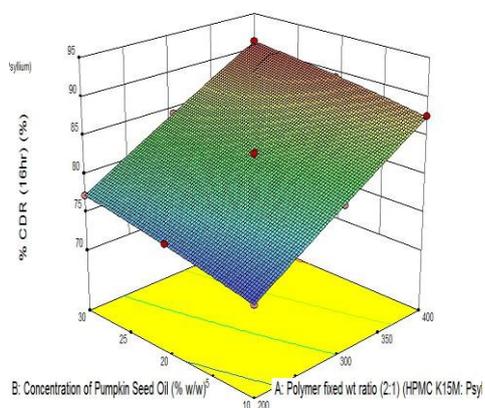
(B) Response Surface Plot

Fig. 2. A) Counter Plot and (B) Response Surface Plot of the Effect of Polymer fixed ratio HPMCK15M: Psyllium(2:1) and Pumpkin Seed Oil on Percentage Drug Release in 1 Hr
**Polynomial Equation*

$$\% \text{CDR (1Hr)} = + 15.62 + 2.91 \times A + 0.92 \times B + 0.055 \times AB - 0.078 \times A^2 - 0.29 \times B^2$$



(A) Counter Plot



(B) Response Plot

Fig. 3. A) Counter Plot and (B) Response Surface Plot of the Effect of Polymer fixed ratio HPMCK15M: Psyllium (2:1) and Pumpkin Seed Oil on Percentage Drug Release in 16 Hr
**Polynomial Equation*

$$\% \text{CDR (16Hr)} = +82.69 + 7.02 \times A + 1.93 \times B - 0.15 \times AB - 0.19 \times A^2 - 0.23B^2$$

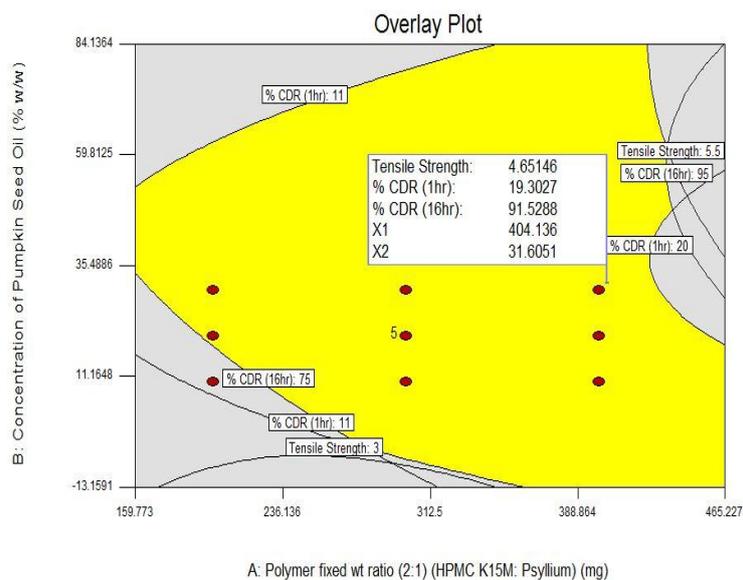


Fig. 4. Overlay Plot Showing Combined Effect of Both the Independent Factors X₁ and X₂ for Batches P1 to P9

Table 4. Observed and predicted results of checkpoint validation analysis

Batch Code	X ₁	X ₂	% CDR up to 16 h (Q 16h)		% CDR in 1 h (Q 1h)		Tensile Strength Kg/cm ²	
			Act. value	Pred. value	Actual Value	Pred. value	Actual Value	Pred. value
L1 (LH)	404	31.60	89.95	91.52	18.19	19.30	4.56	4.65
L2 (LH)	401	30.26	89.13	90.33	18.17	19.81	4.54	4.46

For Lercanidipine hydrochloride – (t_{cal}) value– 2.21 and (t_{tab}) value– 2.31

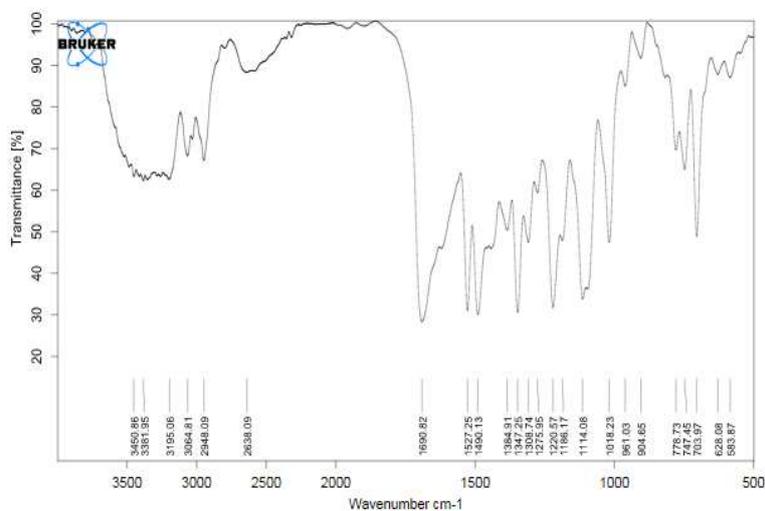


Fig. 5. Infrared spectra of lercanidipine hydrochloride

4. DISCUSSION

From the obtained results, t (cal) and t (tab) values were found to be 2.21 and 2.31. Here, the t (cal) value was less than t (tab) values for all responses at all the levels, which suggested that there were no significant differences between the two results. The t-test value also suggested that obtained results are nearer to predicted values which shows that, the generated model is how much valid for the final optimization of the final formulation.

4.1 FTIR Study

Infrared spectra of L.H. pure drug (A) and L.H. loaded matrix patch final Formulation (B) are shown in [Fig. 4,5]. Infrared absorption spectroscopy (I.R.) of L.H. shows a sharp band

due to stretching vibration bands of CH₃ bending, C-H aromatic Stretching, NO₂, and C=O stretching, respectively. Shown in Table. 5, and from [Fig. 5,6], it was observed that there were no changes in these prominent peaks in I.R. spectra of a mixture of drug and polymers, which indicate physical compatibility between L.H. and all ingredients used in the final Formulation of the transdermal matrix patch [36].

4.2 Differential scanning Calorimetry (DSC) Analysis

DSC peak of Lercanidipine hydrochloride shown in Fig 7. and DSC curve of P9 formulation shown in Fig 8. The DSC peak elucidations for drug alone and powder mixture are represented in Table 6 [36].

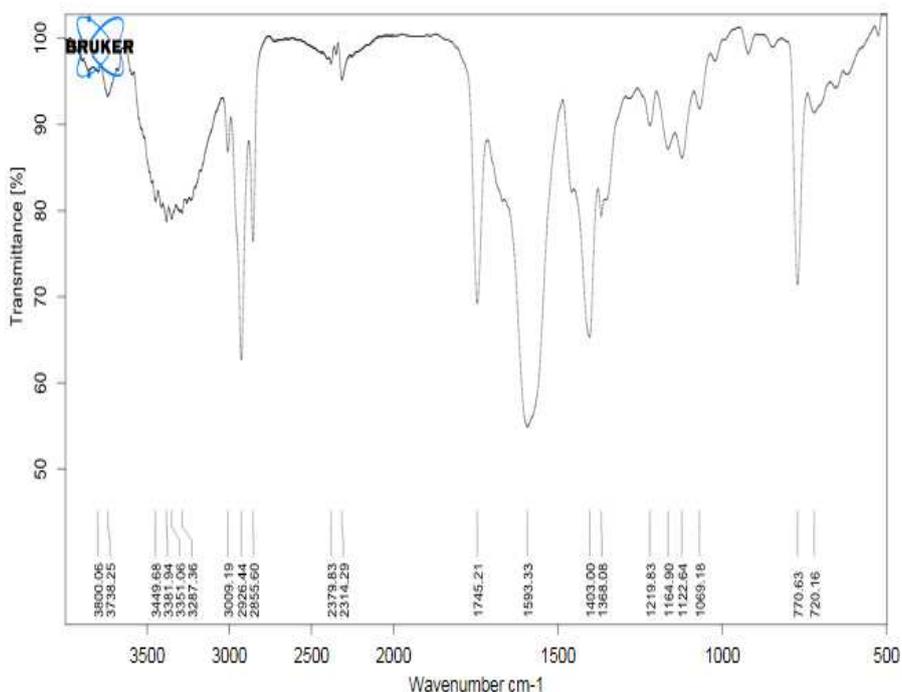


Fig. 6. Infrared spectra of drug-polymer mixture formulation

Table 5. FTIR spectra interpretation

Sr. No.	Frequency of principal peaks in IR spectra of pure drug cm ⁻¹	Frequency of principal peaks in IR spectra of Drug-Polymer Mixture cm ⁻¹	Observation
C-H aromatic stretching	3078.8	3009.19	No interaction
-NO ₂	1347.02	1368.08	No interaction
>C=O stretching	1672.96	1745.21	No interaction
-CH ₃ bending	786.53	720.16	No interaction

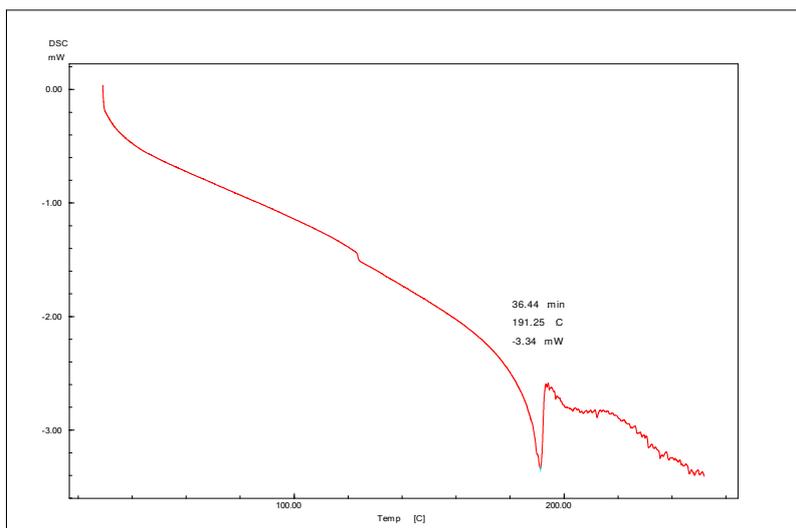


Fig. 7. DSC spectra of lercanidipine hydrochloride pure drug

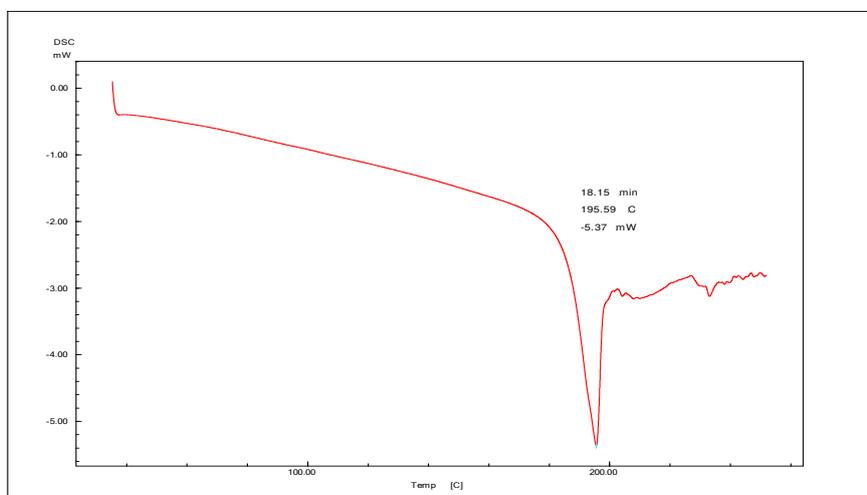


Fig. 8. DSC spectra of batch P9 drug-polymer mixture

Table 6. DSC peak Interpretation

Sr. No.	Sample	DSC Peak(°C)
1	Lercanidipine hydrochloride	191.25
2	Drug-Polymer Mixture	195.59

4.3 Preliminary Trial Study for the Optimization of Matrix Patch Formulation

The preliminary trial batches were prepared and evaluated to investigate the effect of formulation variables such as L.H. concentration, HPMC K15M and psyllium concentration, essential oils concentration as a permeation enhancer on

permeation of L.H. from the transdermal matrix patch. Obtained results are outlined in above [Table 1], it revealed that as an increase in L.H. concentration from 8mg, 10mg, and 12mg, % cumulative drug release was also increased from 68.27±0.19 % (L1), 73.91±0.27% (L2) and 79.13±0.17% (L3), respectively. This increase in a release is based on Fick's first law of diffusion, in which the drug release is directly proportional to the drug concentration gradient across the

membrane, i.e., a higher amount of drug available for diffusion. The results of batches L4, L5, and L6 suggested that the rate of drug release decreased with an increase in polymer concentration. Batch L4 contains 3%w/v of polymer concentrations shows highest drug release ($68.27 \pm 0.19\%$) compare to L5 ($57.79 \pm 0.21\%$) and L6 ($50.32 \pm 0.19\%$) which contains 4%w/v and 5%w/v, respectively. This appears to be due to an increase in the thickness of the polymer matrix with an increase in polymer concentration. Obtained results of batches PE 1 to PE 7 revealed that permeation increase with an increase in the concentration of essential oils. This is evident from the L.H. permeation at 16 hrs from formulations PE 2 to PE 7 containing L.O., J.O., and PSO with two different concentrations, 10%w/w and 20%w/w. The results in [Fig. 9] also indicate that L.O. and J.O. were not sufficient to achieve the desired permeation flux for the controlled release of L.H. up to 16 hrs. On the other hand, 20% w/w PSO achieves the nearer targeted flux value $157.24 \mu\text{g}/\text{cm}^2/\text{hr}$. It was sufficient for controlled release of L.H. up to 16 hrs and to maintain therapeutic plasma level. Thus, PSO's concentration was selected as one independent variable for further study. Briefly, the effect of the above formulation variables on L.H. release in the preliminary trial suggested that the amount of L.H. released from the patch increased with an increase in L.H. concentration PSO concentration and decreased with an increase in polymer concentration.

4.5 Statistical Optimization of the Formulation Variables

Based on the results of the preliminary studies, further evaluations of formulation variables were performed using experimental designs to optimize a suitable combination of independent factors on the fabrication of transdermal matrix patch of L.H. having a desired rate of drug release as well as permeation flux. A 3^2 full factorial design nine batches are summarized in [Table 2]. Drug release at 1hr (Q1), at 16th hr (Q16), and tensile strength selected as dependent variables to find out the final Formulation for the L.H. containing transdermal matrix patch. Prepared nine batches P1 to P9 further evaluated for the physicochemical properties of Matrix patch. Cumulative drug release of L.H. from Matrix patch and its permeation through the rat skin shown in [Fig.

10], results of dependent variables listed in [Table 3].

4.6 Physicochemical Evaluations of LH Containing Transdermal Matrix Patch

Transparent, flat, flexible, and uniform transdermal diffusional matrix patch obtained using a mixture of natural polymer psyllium and synthetic polymer HPMC K15M. The average weight of batches P1 to P9 ranges between 362 ± 1.732 to 524 ± 2.31 mg, which indicates that all the solid excipients uniformly dispersed into the liquid and all batches were relatively in similar weights; the thickness of the patches measured by micrometer screw gauze results was found in between 0.81 ± 0.04 to 0.88 ± 0.13 mm. The results revealed that the solution was uniformly cast on a previously lubricated Petri plate and solvent uniformly evaporated from the Petri plate. The drug content of the entire batches lie between 92.85 to 97.60 %, and these results revealed that the method selected for the preparation of the matrix patch was suitable and reproducible. The results of the flatness study showed that all the batches have the same length before and after cuts. Therefore, nearer to 100% flatness was obtained, and it indicates that all patches had a smooth surface. Tensile strength was found between 7.03 ± 0.136 to $8.48 \pm 0.127 \text{ gm}/\text{cm}^2$, which revealed that the patch had sufficient mechanical strength to withstand handling, transportation, and administration. The same way results of the folding endurance study showed that the patch would not break and maintain their integrity with general skin folding applied. The results are listed in (Table 7) [35,36,51,52].

4.7 Ex-vivo Skin Permeation Study of L.H.

Permeation studies plot of the cumulative amount of drug release versus time was generated and represented in (Fig. 10); from this plot, permeation flux, permeability coefficient, and enhancement ratio were calculated. The results are listed in [Table 8]. The results revealed that batch P9 containing 30%w/w of PSO exhibited the highest flux, $164.09 \pm 0.14 \mu\text{g}/\text{cm}^2/\text{hr}$ and 89.93% drug release in 16 hrs. This higher release and permeation occur due to the presence of higher content of fatty acids of PSO. The results of the *ex-vivo* release also suggested that the concentration of PSO and P.G. both had a major influence on drug release because fatty acids of PSO increase the lipid

fluidity and P.G. water fluidity. Data of *ex-vivo* release fit into different kinetic models to find out release mechanism, the release profiles of the drug seemed to follow zero-order, and drug release mechanism was diffusion controlled so, it followed the Higuchi model [52]. The correlation coefficient of R^2 values of batch P9 was $r^2 = 0.9976$ for zero-order and $r^2 = 0.9733$ for Higuchi model. A plot of kinetic studies is represented in [Fig. 11-12].

4.8 Regression Analysis of the Optimization of Formulation

Based on the values of dependent variables, polynomial equations were generated and listed with 3D and contour response surface plots,

which indicates that both the formulation variables X1 and X2 played an essential role in a controlled release of drugs from the transdermal matrix patches. Tensile strength increases with the optimum concentration of P.G. (20%w/w) and PSO (30%w/w). Obtained results revealed that the selected model was significant, and the drug was released in a controlled manner for a period of 16 hrs.

4.9 Stability Study

The batch P9 was exposed to stability studies as per ICH guidelines. The results are listed in [Table 9] and reveal that prepared patches are stable and maintain their physical integrity throughout the study.

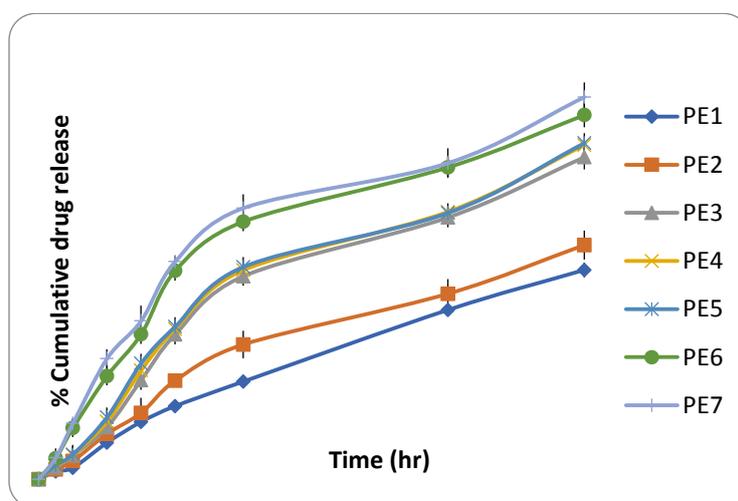


Fig 9. Comparative drug release profile of batches PE1-PE7

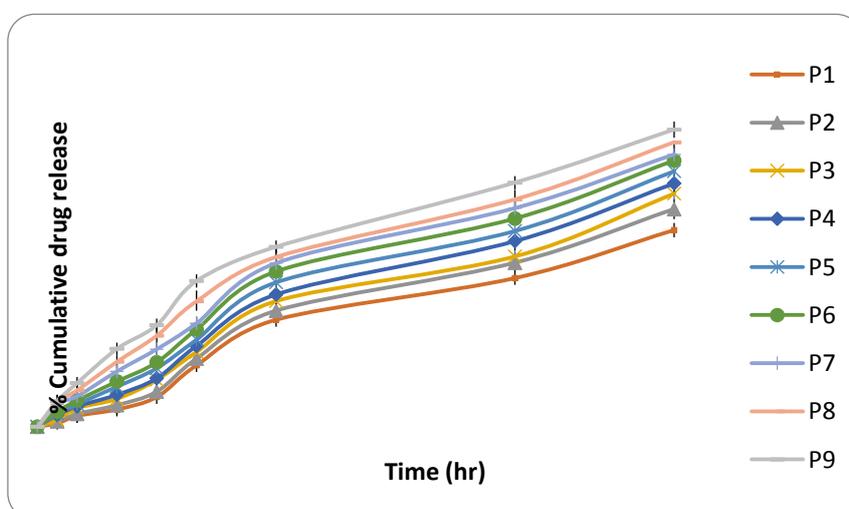


Fig.10. Comparative drug release profile of batches P1-P9

Table 7. Physicochemical Evaluation of L.H. Loading Batches P1 to P9. Average of Triplicate Results. Mean ± S.D. (Standard Deviation)

Batch Code	Weight variation(mg)	Thickness (mm)	Folding endurance	Tensile strength (kg/cm ²)	% Elongation	%moisture Uptake	% moisture Loss
P1	362 ± 1.732	0.84±0.03	335±3.511	7.78±0.15	17.96±0.587	1.88 ± 0.07	2.84 ± 0.09
P2	408 ±2.516	0.86±0.08	348±3.7859	7.03±0.136	18.93±0.450	2.16 ± 0.20	2± 0.06
P3	457 ± 1.527	0.88±0.02	361±3.605	7.21±0.245	18.96±0.585	2.68± 0.06	2.23± 0.03
P4	387 ± 2.087	0.85±0.09	390±4.041	7.32±0.359	19.26±0.351	2.32± 0.08	2.72± 0.05
P5	433 ± 1.127	0.85±0.01	398±6.0277	8.16±0.245	19.50±0.684	2.89± 0.05	2.85± 0.05
P6	486 ± 1.527	0.88±0.07	397±4.00	7.17±0.125	20.46±0.493	2 ± 0.36	1.88± 0.08
P7	425 ± 2.00	0.86±0.11	373±3.605	7.91±0.183	22.50±0.458	1.98 ± 0.11	1.98± 0.09
P8	478 ± 1.527	0.81±0.04	378±2.00	7.76±0.15	20.98±0.602	2.83± 0.05	2.85± 0.06
P9	524 ± 2.51	0.88±0.013	384±3.21	8.48±0.127	21.84±0.335	2.50 ± 0.06	2.5± 0.13

Table 8. Results of L.H. Transdermal Flux and Lag Time, Permeability Coefficient, Diffusion Coefficient, and Enhancement Ratio of Batches P1 to P9. Average of Triplicate Results. Mean ± SD(Standard Deviation)

Batch Code	Transdermal Flux Jss (µg/cm ² /hr) ±SD	Lag time (hours)	Permeability Coefficient (Kp) (cm/hr) ±SD	Diffusion Coefficient (D) (cm/h×10-8) ±SD	Enhancement Ratio
P1	97.30±0.11	1.25±0.11	1.21×10 ⁻³ ±0.21	0.01306±0.11	1.223±0.01
P2	99.17±0.12	1.30±0.12	1.29×10 ⁻³ ±0.22	0.01398±0.12	1.113±0.02
P3	119.6±0.12	1.34±0.12	1.48×10 ⁻³ ±0.22	0.01416±0.13	1.343±0.03
P4	117.6±0.13	1.35±0.13	1.46×10 ⁻³ ±0.23	0.0154±0.14	1.314±0.04
P5	127.4±0.14	1.38±0.14	1.58×10 ⁻³ ±0.24	0.0156±0.15	1.426±0.05
P6	129.6±0.15	1.29±0.01	1.61×10 ⁻³ ±0.25	0.022±0.16	1.449±0.06
P7	137.8±0.16	1.31±0.11	1.71×10 ⁻³ ±0.26	0.023±0.17	1.539±0.07
P8	151.2±0.17	1.30±0.12	1.78×10 ⁻³ ±0.27	0.026±0.18	1.606±0.08
P9	164.3±0.18	1.25±0.2	1.86×10 ⁻³ ±0.28	0.0345±0.19	1.674±0.09

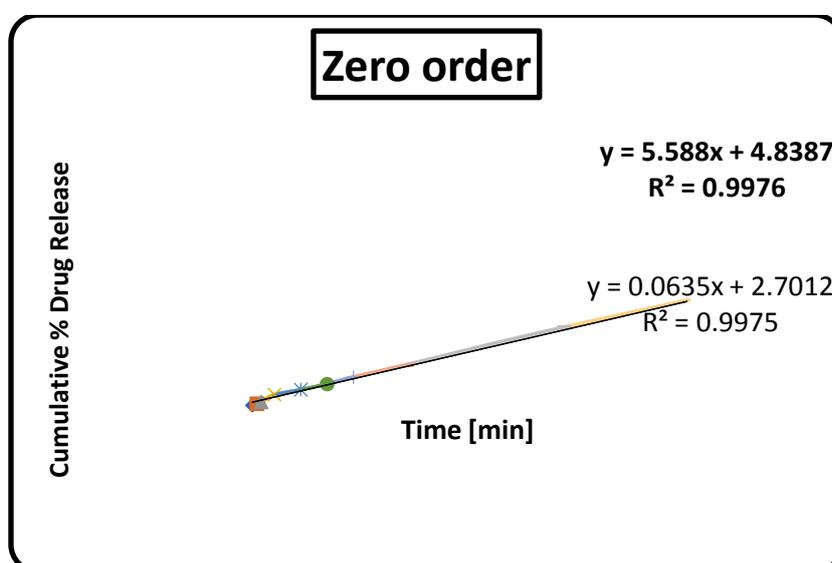


Fig. 11. Zero-Order Plot for Model Release Kinetic for Batch P9

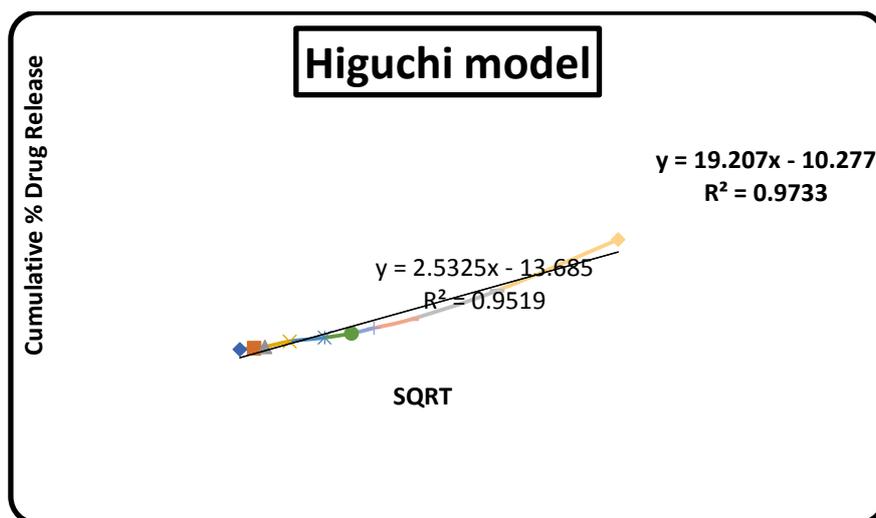


Fig. 12. Higuchi Plot for Model Release Kinetic of Batch P9

Table 9. Stability Studies Results of Batch P9

Stability conditions	Sampling time	Folding endurance	Drug content uniformity (%)	Ex-vivo drug release (%)	Visual appearance
Room Storage (30±2°C and 65±5% RH)	Initial (0 day)	398±1.52	98.39±0.65	93.14±0.85	Clear homogeneous appearance
	After 15 days	398±1.06	98.11±0.21	93.10±0.80	Clear homogeneous appearance
	After 30 days	398±2.64	98.34±0.65	93.12±0.09	Clear homogeneous appearance
	After 90 days	397±2.98	98.77±0.65	93.07±0.89	Clear homogeneous appearance
	After 180 days	397±3.65	98.12±0.12	92.94±0.54	Clear homogeneous appearance
Accelerated condition (40±2°C and 75±5% RH)	Initial (0 day)	198±1.52	98.45±0.65	90.37±0.88	Clear homogeneous appearance
	After 15 days	218±1.98	98.89±0.35	82.12±0.42	Clear homogeneous appearance
	After 30 days	197±2.98	98.37±0.64	85.07±0.87	Clear homogeneous appearance
	After 90 days	193±3.65	97.19±0.17	86.34±0.54	Clear homogeneous appearance
	After 180 days	230±1.52	96.45±0.65	89.65±0.82	Clear homogeneous appearance

5. DISCUSSION

The present investigation aimed to fabricate and evaluate a transdermal patch of Lercanidipine hydrochloride (L.H.) for the treatment of hypertension. In this study, a patch was prepared using Psyllium and HPMC K15M by a solvent evaporation method. To overcome the barrier of stratum corneum for drug permeation through the skin, essential oils, namely linseed oil, jojoba oil,

and pumpkin seed oil used as permeation enhancers. The batch 9 had excellent transparency, mechanical strength, and compatibility with other ingredients. The controlled release of drug up to 16 hrs well-observed physicochemical and mechanical properties of matrix patch would be beneficial for the treatment of hypertension with more patient compliance. The use of natural permeation enhancers and polymer makes this research

work novel and attractive because they are naturally available with some benefits as well as more economical, capable with any type of physical and chemical modifications.

To study the compatibility between drug and excipients, Fourier transforms infrared spectroscopy, and Differential scanning Calorimetry study performed and obtained results shows the absence of any type of interactions. The transdermal patch of Lercanidipine hydrochloride was prepared with HPMC K15M (200 mg), Psyllium (100 mg), pumpkin seed oil (30 %w/w of dry wt of polymer), propylene glycol (20 % w/w of dry wt of polymer) by a solvent evaporation method. This method prepared matrix diffusion controlled transdermal patch, which will improve the therapeutic efficacy and safety of drugs by more precise (i.e., site-specific) placement within the body and releasing the drug at a controlled rate into the systemic circulation without the use of electric current or other electrically heated devices which may distort the stratum-corneum. Prepared drug-loaded patches were evaluated for all physicochemical and mechanical parameters such as folding endurance, tensile strength, flatness, thickness, hardness, weight variation, % moisture uptake, and loss, drug content, *ex-vivo* permeation study using Wistar rat, skin irritation study, and stability study. Folding endurance and tensile strength of batch P9 was found to be 384 ± 3.21 and 4.55 kg/cm^2 , and respectively, these obtained results indicate that prepared patches have sufficient mechanical strength.

To study the drug release from the matrix patch, the *ex-vivo* skin permeation study was performed using Franz-diffusion cell, Wistar rat skin was used as a membrane, and phosphate buffer pH 6.8 was used as a receptor medium at 37°C . Drug permeation of L.H. optimized batch was found to be 89 %. Stability study showed that transdermal patch containing Psyllium and pumpkin seed oil was stable at accelerated conditions (40°C and 75 % R.H.) for 180 days. Thus, the patch was successfully prepared for overcoming the drawbacks of oral administration of selected antihypertensive drugs.

6. CONCLUSION

LH is the potent antihypertensive agent and is very widely used in the treatment of hypertension, but due to the first-pass hepatic metabolism, drug bioavailability decreases.

Therefore, in the present study, the transdermal patch of L.H. was prepared, and Batch P9 which consists of Polymer fixed ratio of HPMCK15M: Psyllium(2:1) (300 mg) and PSO(% w/w) respectively together in 1:1 ratio has shown acceptable physicochemical and satisfactory *ex-vivo* controlled release after 16 hrs and Stability study could help overcome the drawbacks of oral administration of selected antihypertensive drugs for the treatment of hypertension with improved patient compliance even though extensive clinical studies are required to prove control release of L.H. from the transdermal matrix patch on human.

DISCLAIMER

The products used for this research are commonly and predominantly used in our area of study and country. There is no conflict of interest between authors and producers of the products because we do not intend to use these products as an avenue for litigation but for the advancement of knowledge. Also, the research was not funded by the producing company. Instead, it was supported by the personal efforts of the authors.

CONSENT

It is not applicable.

ETHICAL APPROVAL

The animals received after the study was duly approved by the CPSCEA (committee for the purpose of control and supervision on experiments on animals of the government of India) with protocol No. 984/06/2014-2-06.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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