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# Formulation and evaluation of transdermal patches of meloxicam

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**Abstract**
The present study aimed to formulate and evaluate matrix-type transdermal patches of Meloxicam using the solvent casting method with ethyl cellulose (EC) and polyvinylpyrrolidone K-30 (PVP K-30) as rate-controlling polymers. The formulations were prepared using PEG 200 as a plasticizer, DMSO as a penetration enhancer, and triethanolamine to adjust pH to skin-compatible levels (6.5-7). Nine formulations (F1-F9) were developed by varying the ratio of EC and PVP K-30. The prepared patches were evaluated for physical characteristics, thickness, weight variation, drug content, folding endurance, surface pH, moisture uptake, moisture content, swelling index, *in vitro* drug release, release kinetics, and stability. All patches exhibited satisfactory physical properties with uniform thickness, weight and drug content. The folding endurance ranged from 115 to 128, indicating good mechanical strength. Surface pH (6.6-6.8) confirmed skin compatibility. Moisture uptake and moisture content were within acceptable limits, ensuring patch stability. Swelling studies revealed that patches with higher PVP K-30 content showed greater water absorption due to its hydrophilic nature, while EC imparted structural integrity. *In vitro* drug release studies indicated that increasing the content of hydrophobic EC retards the release, whereas the inclusion of hydrophilic PVP K30 enhances it. Batch F7 offered a balanced release profile and considered optimal for sustained transdermal delivery of meloxicam that folowes Korsmeyer-Peppas kinetics, indicating a non-Fickian diffusion mechanism. Stability studies demonstrated no significant changes in drug content or appearance over 3 months. The study concluded that meloxicam transdermal patches using an optimal blend of EC and PVP K-30 can provide controlled drug delivery with desirable physicochemical and mechanical properties, offering a promising alternative to oral administration.

**Keywords:** Meloxicam, transdermal drug delivery system, PVPK30, ethyl cellulose etc.

## Introduction
Transdermal drug delivery systems (TDDS) represent a pivotal advancement in pharmaceutical technology, offering a non-invasive and convenient means of administering therapeutic agents through the skin for systemic distribution. Unlike conventional routes of drug administration such as oral ingestion or injections, transdermal delivery bypasses the gastrointestinal tract and avoids first-pass metabolism, potentially enhancing drug bioavailability and therapeutic efficacy while minimizing systemic side effects. This innovative approach utilizes the skin's unique properties as a barrier and a reservoir, allowing for controlled release of medications over extended periods, thus improving patient compliance and overall therapeutic outcomes [1]. Transdermal Drug Delivery System (TDDS) are defined as self-contained, discrete dosage which is also known as patches [2]. A transdermal patch or a skin patch is a medicated adhesion with minimal inter and intra patient variation. The main objective of transdermal drug delivery system is to deliver drugs into systemic circulation into the skin through skin at predetermined rate with minimal inter and intra patient variation [3, 4]. That will improve bioavailability, more uniform plasma levels, longer duration of action resulting in a reduction in dosing frequency, reduced side effects and improved therapy due to maintenance of plasma levels up to the end of the dosing interval compared to a decline in plasma levels with conventional oral dosage forms. The development of transdermal delivery systems has revolutionized the treatment of various medical conditions ranging from chronic pain management to hormone replacement therapy. By harnessing the principles of diffusion, permeation, and drug partitioning across the skin

layers, TDDS can deliver a wide range of drugs, including small molecules, peptides, and even nanoparticles. This versatility has opened new avenues for drug development and expanded the therapeutic options available to patients [5]. Meloxicam, a selective cyclooxygenase-2 (COX-2) inhibitor, is widely used for the treatment of rheumatoid arthritis, osteoarthritis, and other inflammatory conditions due to its potent anti-inflammatory, analgesic, and antipyretic properties. However, the oral administration of Meloxicam is often associated with limitations such as poor aqueous solubility, variable gastrointestinal absorption, and potential gastrointestinal irritation. These drawbacks can be minimized through transdermal delivery, which maintains steady plasma drug concentrations and reduces dosing frequency. The development of a transdermal patch for Meloxicam can thus improve its therapeutic efficacy while minimizing systemic side effects. This research focuses on the formulation and evaluation of Meloxicam transdermal patches using various polymers to optimize drug release and skin permeability. Different combinations of film-forming polymers such as Ethyl cellulose (EC), and Polyvinyl pyrrolidone (PVP) are employed to develop patches with desirable mechanical strength, flexibility, and sustained drug release. Plasticizers like polyethylene glycol (PEG) are incorporated to enhance the patch's physical properties. The ultimate goal of this study is to develop a patient-friendly and effective transdermal system that enhances Meloxicam's bioavailability and therapeutic outcomes.

## Materials and Methods

### Materials

Meloxicam was received as gift sample from Cipla ltd, Mumbai. Ethyl Cellulose and PVP K 30 was purchased from S. D. Fine Chemicals. All other solvents and reagents were of analytical grade.

### Method

### Formulation of Meloxicam Transdermal Patch

Matrix type of meloxicam containing transdermal patch was prepared by solvent casting method using two rate controlling polymers like ethyl cellulose and PVP K 30. All the ingredients were weighed accurately and dissolved in a mixture of solvent (Chloroform and methanol in 1:1 ratio) with continuous stirring. Then plasticizer plasticizer PEG 200 (40% of polymer weight) and DMSO as penetration enhancer was then added to the above solution. Finally, triethanolamine was added drop wise to above mixture in order to achieved the required skin pH condition (6.5 to 7). The resultant solution was stirred for 15 min under mechanical stirring at 400 rpm (Remi, India) at a lower temperature 50 ºC. to get a clear solution and was kept aside for some time so as to remove the air bubble from solution. Finally, patches were obtained by casting the solution in prelubricated petri dish with glycerine and was allow to dry by placing inverted funnel on it, so as to facilitated controlled drying for 24 hours at room temperature. The dry films were removed and cut in required size (2x2 cm) and then wrapped in aluminium foil and kept in a dessicator until used [6, 7]. The details for the formulation of Meloxicam transdermal patch was shown in table 1.

**Table 1:** Composition of Meloxicam Transdermal Patch

| Batch Code | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 |
|---|---|---|---|---|---|---|---|---|---|
| Meloxicam (mg) | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 |
| Ethyl Cellulose (mg) | 50 | - | 100 | - | 50 | 60 | 70 | 80 | 90 |
| PVP K-30 (mg) | - | 50 | - | 100 | 50 | 40 | 30 | 20 | 10 |
| PEG 200 (mg) | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| DMSO (ml) | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Triethanolamine | q.s. | q.s. | q.s | q.s | q.s | q.s | q.s | q.s | q.s. |
| Chloroform: Methanol (1:1) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |

## Evaluation of Transdermal Patches

### Physical Appearance

All the prepared patches were visually inspected for colour, clarity, entrapment of any air bubble, flexibility and smoothness.

### Thickness

Thickness of the prepared patch was measured by using screw gauge. The reading of thickness was determined at three different points and average thickness was determined [8].

### Weight Variation

10 patches from each formulation were weighed individually and the average weight was calculated. The individual weight should not deviate significantly from the average weight [9].

### Drug Content

A specified area 2x2cm of patch was dissolved in mixture of chloroform and methanol. It was closed and shacked vigorously for 24 hours in a shaker. The resulting solution was filtered and the amount of drug present in the filtrate was determined by using UV spectrophotometer at 360 nm [10].

### Folding Endurance

Folding endurance of the patches was determined by repeatedly folding one patch at the same place till it either breaks or develops visible cracks on folding number of times manually, which was considered satisfactory to reveal good patch properties. This is important to check the ability of sample to withstand folding. This also gives an indication of brittleness. The number of times the films could be folded at the same place without breaking gives the value of folding endurance [11, 12].

### Surface pH

The patches were allowed to swell by keeping them in contact with 0.5 ml of double distilled water for 1h in glass tubes. The surface pH was then noted by bringing a combined glass electrode near the surface of the patch and allowing it to equilibrate for 1 min.

**Percentage Moisture Uptake:** The patches were weighed accurately and placed in a desiccator where a humidity

condition of 80-90% RH was maintained by using saturated solution of potassium chloride. The patches were kept until uniform weight is obtained, then taken out and weighed. The percentage of moisture uptake was calculated as the difference between final and initial weight with respect to initial weight [13].

% Moisture Absorption=(Final Wt.-Initial Wt.)/(Initial Wt.) X 100

**Percentage Moisture Content**

The prepared films are weighed individually and kept in a desiccators containing calcium chloride at room temperature for 24h. The films are weighed again after a specified interval until the show a constant weight. The percent moisture content is calculated as the difference between final and initial weight with respect to final weight. The following formula was utilised to calculate the percentage moisture loss [14].

% Moisture Loss=(W1 -W2)/(W1) X 100

Where, W1 = Initial weight of the transdermal patch (mg)
W2 = Final weight of the transdermal patch after drying (mg)

**Swelling study:** The formulated transdermal patches were weighed (W1) individually and incubated at 37±0.5 ° C separately in agar gel (2%) plate. The patches were removed from the petri dish at regular time intervals of every 15 min up to 1 h and the excess water on the surface was removed carefully with filter paper. The swollen patches were reweighed (W2) and the swelling index was calculated by using the formula [15, 16].

Swelling Index (%)=(W2 -W1)/(W1) X 100

***In vitro* release studies**

The release studies were performed using Franz diffusion cell, generally comprise of two compartments, one containing the active donor compartment and the other containing receptor solution (receptor compartment), separated by barrier i.e. membrane. The cell consisted of sampling port and temperature maintaining jacket. The outlet and inlet was connected with latex tube so the jacket had stagnant water inside and heat was provided by hot plate. The stainless steel pin was used to stir the receptor solution using magnetic stirrer. A dialysis cellulose membrane was used as artificial membrane and was placed on receptor compartment and both compartments held tight by clamps. Phosphate buffer pH 7.4 was used as receptor medium. The volume of diffusion cell was 10 ml and stirred with bent stainless steel pin. The temperature was maintained at 37±1°C with the help of hot plate. The study was carried out for 24 hours and at predetermined time interval 1 ml sample was withdrawn and the same volume of phosphate buffer pH 7.4 was added to receptor compartment to maintain sink conditions. The withdraw sample was analysed spectophotometrically at 360 nm [17, 18].

**Drug release kinetics**

The *in-vitro* drug release data were fitted to various kinetic models: Zero-order, First-order, Higuchi, and Korsmeyer-Peppas to determine the drug release mechanism. The Korsmeyer-Peppas model was further used to determine the release exponent (n) to characterize the drug release mechanism [19].

**Stability study**

Accelerated stability studies were conducted on the optimized formulation by storing the product in aluminum foil strips in a stability chamber maintained at 40 °C and 75% RH for 3 months, according to ICH guidelines. The tablets were evaluated for changes in appearance, hardness, disintegration time, drug content, and *in-vitro* drug release at initial time points and after 3 months [20].

**Results and Discussion**

Transdermal patches loaded with meloxicam was prepared by solvent casting method using two rate controlling polymers like ethyl cellulose and PVP K 30 in varied amount. FT-IR study revealed that there is no chemical interaction between the polymer and meloxicam. The major peak in the drug and polymer mixture's infrared spectra was found to remain unchanged, indicating that there was no physical interaction due to bond formation between the two substances. All the prepared patches were visually inspected for colour, clarity, entrapment of any air bubble, flexibility and smoothness. It was observed that all prepared patches had an characteristics colour and all patches formulation were free of bubble. All prepared patches shown smooth surface and enough flexibility.

**Thickness, weight variation and drug content**

Thickness of the patch was measured by using screw gauge. The thickness of the formulated batches (F1-F9) ranged from 0.208 mm to 0.232 mm, with slight variations observed among different formulations. The lowest thickness was recorded for batch F1 (0.208±0.012 mm), while the highest was observed for batch F9 (0.232±0.018 mm). The standard deviation values indicate minimal variability within each batch, suggesting good uniformity of patch thickness.

The weight variation results for different batches (F1-F9) of transdermal patches ranged from 26.15 mg to 29.70 mg, indicating slight differences in patch weights across batches. Batch F1 exhibited the lowest mean weight (26.15±1.33 mg), while batch F6 showed the highest mean weight (29.28±1.06 mg). The standard deviation values suggest that all batches have minor deviations from their respective means, indicating good uniformity in weight distribution.

The drug content analysis of transdermal patches across different batches (F1-F9) revealed values ranging from 96.44% to 99.14%, indicating consistent drug loading within the formulations. The highest drug content was observed in batch F5 (99.14±0.66%), while the lowest was found in batch F6 (96.44±0.61%).

**Table 2:** Evaluation Parameters of Transdermal Patches of Meloxicam

| Batch | Thickness (mm)±SD* | Folding Endurance ±SD* | Drug content (%)±SD* | Weight Variation (mg)±SD* | Surface pH (%) | % Moisture Uptake* | % Moisture Content* |
|---|---|---|---|---|---|---|---|
| F1 | 0.208±0.012 | 120±3.20 | 97.61±0.51 | 26.15±1.33 | 6.8 | 7.12±0.51 | 1.78±0.22 |
| F2 | 0.209±0.011 | 124±2.75 | 98.13±0.34 | 26.61±1.43 | 6.7 | 8.18±0.37 | 2.10±0.17 |
| F3 | 0.212±0.014 | 115±3.78 | 98.23±0.54 | 28.14±1.20 | 6.6 | 7.10±0.60 | 1.84±0.21 |
| F4 | 0.221±0.016 | 126±4.12 | 97.04±0.65 | 27.20±2.14 | 6.7 | 8.20±0.35 | 2.03±0.15 |
| F5 | 0.230±0.015 | 128±5.22 | 98.31±0.64 | 28.62±1.61 | 6.7 | 8.32±0.81 | 2.16±0.22 |
| F6 | 0.232±0.012 | 126±4.31 | 97.30±0.56 | 29.28±1.06 | 6.8 | 7.26±0.67 | 1.64±0.10 |
| F7 | 0.230±0.018 | 125±3.63 | 99.14±0.48 | 26.82±1.38 | 6.7 | 7.32±0.46 | 1.45±0.14 |
| F8 | 0.231±0.015 | 124±2.65 | 96.44±0.74 | 28.12±2.17 | 6.8 | 7.24±0.51 | 1.40±0.20 |
| F9 | 0.232±0.018 | 118±3.02 | 97.17±0.66 | 28.10±2.06 | 6.6 | 7.20±0.35 | 1.41±0.18 |

(*All values are mean± SD (n=3)

**Folding Endurance**

A higher folding endurance indicates better resistance to mechanical stress, ensuring the patch remains intact without breaking or losing its integrity over time. The folding endurance test conducted on transdermal patches of meloxicam showed values ranging from 115 to 128, indicating good flexibility and mechanical strength of the patches. The highest folding endurance was observed in batch F5 (128±5.19), while the lowest was noted in batch F3 (115±3.78). The standard deviation values across batches suggest acceptable variability in patch flexibility and mechanical integrity. The results suggest that all batches possess adequate flexibility to withstand daily wear and tear. The observed variations in folding endurance among batches could be attributed to factors such as polymer composition and concentration, which influence the mechanical properties of the patch and plasticizer content, affecting the elasticity and resilience of the formulation. Despite minor differences in folding endurance values, all batches demonstrated sufficient mechanical strength, ensuring they can endure handling and application without breaking or becoming non-functional. From the study it was concluded that, concentration of PEG 200 (40%) is found to be optimum as plasticizer in the development of the transdermal patches of meloxicam, which exhibited satisfactory folding endurance, making them suitable for prolonged application while maintaining their structural integrity and therapeutic effectiveness. The results are shown in table 2 and figure 1.

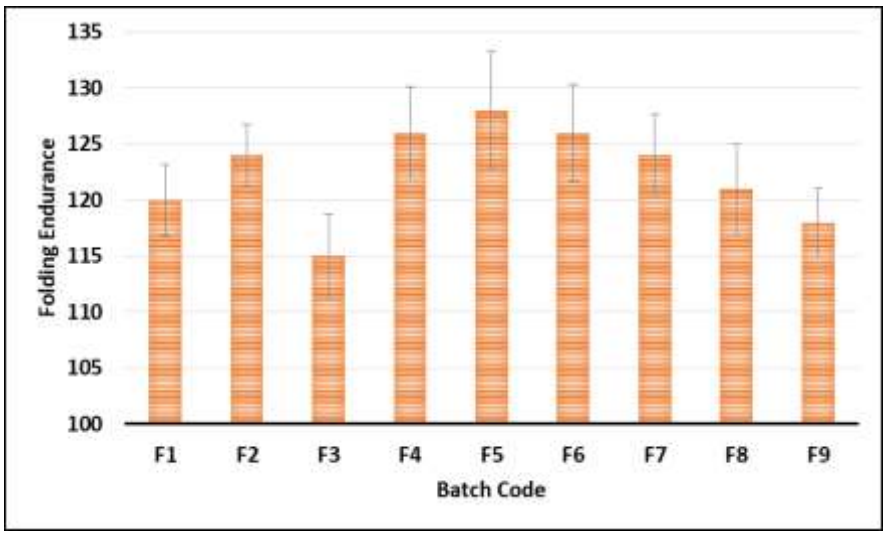


**Fig 1:** Folding Endurance values of Batch formulation F1 to F9

**Surface pH, Percentage Moisture Uptake and Percentage Moisture Loss**

The surface pH of all patches were determined and was found in the range of 6.6 to 6.8, ensuring compatibility of prepared patch formulation with skin.

Moisture uptake is an important parameter that determines the patch's ability to absorb atmospheric moisture, which can influence its mechanical properties, stability, and drug release profile. Higher moisture uptake can lead to increased patch flexibility, but excessive absorption may compromise the integrity and adhesion of the patch, potentially leading to microbial contamination or degradation of the active pharmaceutical ingredient. The moisture uptake of the transdermal patches of meloxicam ranged from 7.10% to 8.32%, indicating varying degrees of hygroscopicity among different formulations. The highest moisture uptake was observed in batch F5 (8.32±0.81%), while the lowest was recorded in batch F3 (7.10±0.60%). The observed values indicate that all patches have a moderate moisture uptake capacity, which ensures sufficient flexibility without compromising their physical integrity.

Moisture content is a critical parameter which directly influences the patch's physical properties, stability, and overall shelf life. The moisture content of the transdermal patches of meloxicam ranged from 1.40% to 2.16%, indicating minimal water retention within the formulations. The highest moisture content was observed in batch F5 (2.16±0.22%), while the lowest was recorded in batch F8 (1.40±0.20%). Batches F2, F4 and F5 exhibited slightly higher moisture content, possibly due to a higher proportion

of hydrophilic polymer (PVP K30) in their formulations, which may have retained more water. Batches F6 to F9, with lower moisture content, suggest better drying efficiency or lower affinity of the excipients used for water retention. The results indicate that all batches have relatively low moisture content, which is beneficial in preventing microbial contamination and ensuring product stability.

**Swelling Study**

The swelling index of the formulated Meloxicam transdermal patches was determined at 15, 30, 45, and 60 minutes, and the results are summarized in Table 3. Among all formulations, the swelling index increased progressively with time across all batches, indicating time-dependent hydration of the polymers used. Formulations containing PVP K-30 alone showed significantly higher swelling indices compared to those containing Ethyl Cellulose (EC) alone. For instance, F2 (PVP K-30, 50 mg) showed a swelling index of 68.43±1.66% at 60 min, whereas F1 (EC, 50 mg) only reached 58.3±0.58%. Similarly, F4 (PVP K-30, 100 mg) exhibited the highest swelling among all formulations at 72.16±1.32% after 60 minutes, which is attributed to the highly hydrophilic nature of PVP K-30, facilitating rapid water uptake and swelling. In contrast, formulations containing only EC (F1 and F3) exhibited relatively lower swelling due to its hydrophobic nature. F3, which had a higher EC concentration (100 mg), showed only a modest increase compared to F1, reaching 61.46±1.67% at 60 minutes, indicating that increasing EC content marginally improves swelling but to a lesser extent than PVP K-30. Combination batches (F5 to F9) demonstrated swelling behavior that varied depending on the ratio of EC to PVP K-30. Batch F5 (EC 50 mg + PVP K-30 50 mg) and Batch F6 (EC 60 mg + PVP K-30 40 mg) exhibited relatively high swelling indices (68.31±2.18% and 66.18±2.89%, respectively), comparable to F4, suggesting that synergistic blending of hydrophilic and hydrophobic polymers can achieve enhanced swelling characteristics. However, as the proportion of PVP K-30 decreased in F7 to F9, the swelling index also declined correspondingly, with F9 (EC 90 mg + PVP K-30 10 mg) showing the lowest swelling among the combination groups (60.45±1.55% at 60 minutes).

These results highlight that PVP K-30 contributes significantly to the swelling capacity of the patches due to its hydrophilic nature, while Ethyl Cellulose acts as a modulator, providing structural integrity and controlling the swelling to prevent excessive hydration that may compromise patch stability. The results for % swelling for different batches are shown in table 3

**Table 3:** Swelling Studies of Transdermal Patches of Meloxicam

| Batch | Swelling Study | | | |
|---|---|---|---|---|
| | **15 min** | **30 min** | **45 min** | **60 min** |
| F1 | 36.26±0.71 | 43.19±1.20 | 51.61±0.63 | 58.3±0.58 |
| F2 | 51.37±1.24 | 59.43±1.55 | 64.12±2.05 | 68.43±1.66 |
| F3 | 42.17±1.12 | 48.9±1.33 | 56.3±1.89 | 61.46±1.67 |
| F4 | 58.67±1.24 | 61.74±2.17 | 67.8±1.56 | 72.16±1.32 |
| F5 | 54.2±0.88 | 57.05±1.67 | 63.17±2.30 | 68.31±2.18 |
| F6 | 51.17±1.45 | 55.18±2.09 | 61.14±1.66 | 66.18±2.89 |
| F7 | 50.03±2.10 | 53.64±1.78 | 60.42±2.16 | 64.27±1.80 |
| F8 | 44.59±1.60 | 50.12±1.24 | 58.3±1.72 | 62.71±1.14 |
| F9 | 41.37±1.45 | 47.38±1.71 | 52.63±1.40 | 60.45±1.55 |

All values are mean±SD (n=3)

***In vitro* Drug Release Study**

The *in-vitro* drug release study was conducted to evaluate the release profile of Meloxicam from various transdermal patch formulations over a 12-hour period. Among the individual polymer formulations, F2 (PVP K30 50 mg) showed the highest drug release within 6 hours (95.37±1.63%) but ceased further evaluation beyond this point due to complete or near-complete drug release. This rapid release is attributed to the hydrophilic nature of PVP K30, which enhances patch hydration and diffusion of the drug. In contrast, F1 (Ethyl Cellulose 50 mg) exhibited a more sustained release pattern, with 97.34±1.23% released over 9 hours. Although both formulations reached high cumulative release, PVP K30 favoured a faster release, while EC provided a more controlled, prolonged release profile. Similarly, F3 (EC 100 mg) released only 63.12±0.72% at 12 hours, confirming that increasing EC content further retards drug diffusion. The influence of polymer concentration is clearly observed when comparing F1 vs. F3 and F2 vs. F4. F4 (PVP K30 100 mg) exhibited a slower release than F2, with 96.18±1.04% at 8 hours and complete release nearly achieved by 9 hours (88.27±1.13%). This suggests that while PVP K30 accelerates drug release, higher polymer content may form a thicker matrix, offering some resistance to drug diffusion.

Combination batches (F5-F9) demonstrated an intermediate release pattern depending on the ratio of EC and PVP K30. The F5 formulation (50 mg EC + 50 mg PVP K30) released 95.47±1.18% at 10 hours, closely resembling the profile of F4. Increasing EC and decreasing PVP K30 content led to gradual reductions in release rates, as observed in F6 to F9. Batch F6 (60 mg EC + 40 mg PVP K30) released 90.71±1.22% at 12 hours. Batch F7 (70 mg EC + 30 mg PVP K30) reached 98.34±0.66% by 12 hours, indicating a slightly faster release compared to F6, likely due to optimal matrix porosity. Batch F8 (80 mg EC + 20 mg PVP K30) released 73.26±0.87%, and batch F9 (90 mg EC + 10 mg PVP K30) showed the slowest release among all, with 69.54±1.55% at 12 hours.

These findings highlight the critical role of polymer ratio in modulating drug release. Increasing the content of hydrophobic EC retards the release, whereas the inclusion of hydrophilic PVP K30 enhances it. Among the combination formulations, F7 offered a balanced release profile neither too fast nor too slow and may be considered optimal for sustained transdermal delivery of Meloxicam. The *in vitro* drug release data for all batch formulation are shown in figure 2.

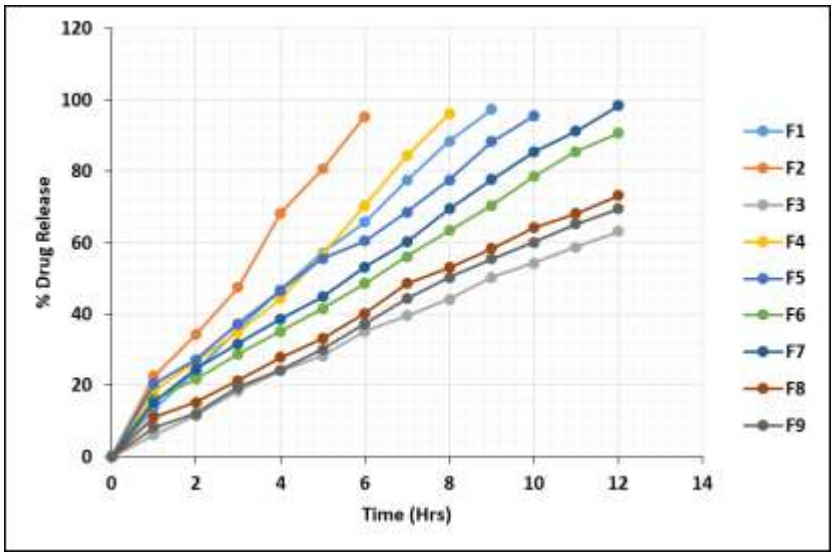


**Fig 2:** Comparative *In-vitro* Drug Release Profile of Formulations F1 to F9

**Drug Release Kinetics**

The drug release kinetics of meloxicam transdermal patches were evaluated using four mathematical models: Zero Order, First Order, Higuchi, and Korsmeyer-Peppas models. The regression coefficient ($R^2$) values were used to determine the best-fitting model for each formulation. (Table 4). The optimized batch (F7) displayed the highest fit for Zero Order kinetics, confirming its potential for maintaining prolonged therapeutic drug levels. To explain the mechanism of drug release for optimized formulation the 'n' value was found to be (0.741) for batch F7, which indicates non-fickian diffusion i.e. combination of diffusion and erosion, which shows that the drug release is sustained by combination approach.

**Conclusion**

The present study successfully formulated and evaluated meloxicam-loaded transdermal patches using the solvent casting method with varying concentrations of ethyl cellulose (EC) and polyvinylpyrrolidone K30 (PVP K30) as rate-controlling polymers. FT-IR studies confirmed the absence of any chemical interaction between the drug and polymers, ensuring the stability of meloxicam within the matrix. All patches exhibited acceptable physical characteristics including uniform thickness, consistent weight, satisfactory drug content, smooth surface, flexibility, and skin-compatible pH. The evaluation parameters revealed that drug content across all batches was within the acceptable range (96.44% to 99.14%), indicating uniform drug distribution. The folding endurance results demonstrated good mechanical strength, especially in formulations containing PEG 200 as a plasticizer. Swelling studies indicated that patches containing higher concentrations of PVP K30 showed greater water absorption due to the hydrophilic nature of the polymer, while EC-based patches displayed lower swelling indices, reflecting its hydrophobic properties. Combination batches (F5-F9) exhibited balanced swelling behavior, supporting the structural stability of the patches. *In vitro* drug release studies demonstrated that PVP K30 alone facilitated faster drug release, whereas EC provided a more controlled release. Formulations containing both polymers showed intermediate profiles, with batch F7 (EC 70 mg + PVP K30 30 mg) achieving a desirable balance between rate and extent of drug release (98.34% over 12 hours). Drug release kinetic analysis further confirmed that batch F7 followed zero-order kinetics with a non-Fickian diffusion mechanism, suggesting a combined diffusion and erosion-controlled release process. Overall, the findings establish that the optimized batch F7 possesses suitable physicochemical characteristics, mechanical properties, and a sustained drug release profile, making it a promising candidate for effective transdermal delivery of meloxicam.

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