FASKES

Jurnal Farmasi, Kesehatan dan Sains (FASKES)
Vol. 4, No. 1, (Juli 2026), P-ISSN : 3025-1508, E-ISSN : 2987-9841

The Effect of HPMC Concentration Variations on the Physical Properties of Semi-Polar Fraction Transdermal Patch Preparations from *Kaempferia galanga* L. Rhizomes

Rini Ambarwati[1], Septia Andini[1], Pedro Prasetyo Atmojo[1], Zaldy Rusli[1]*
[1]Department of Pharmacy, Faculty of Mathematics and Natural Sciences,
Pakuan University Bogor, Indonesia
*) E-mail: zaldy.rusli@unpak.ac.id

Info Artikel
Sejarah Artikel :
Diterima
08-06-2026
Disetujui
18-07-2026
Dipublikasikan
31-07-2026

Keywords:
Kaempferia galanga L., HPMC, transdermal patch, anti-inflammatory, ethyl para-methoxycinnamate

Abstract

***Background*:** Inflammation is a physiological response to infection or injury characterized by redness, swelling, and pain. Ethyl para-methoxycinnamate (EPMC), the major compound in Kaempferia galanga L., exhibits strong anti-inflammatory activity but has poor bioavailability when administered orally.
***Objectives*:** This study aimed to evaluate the effect of Hydroxypropyl Methylcellulose (HPMC) concentration variations on the physical properties of transdermal patches containing semi-polar fractions of K. galanga rhizomes.
***Methods*:** Patches were prepared using HPMC concentrations of 0.5% (F1), 1.0% (F2), and 1.5% (F3). Physical characteristics including pH, water content, thickness, weight uniformity, and folding endurance were evaluated.
***Results*:** Results showed that F3 exhibited the best physical properties: water content 3.77%, pH 6.88, thickness 0.305 mm, weight 0.7434 g, and folding endurance 364 times.
***Conclusions and suggestions*:** All formulations met transdermal patch quality requirements. The F3 formulation demonstrated superior flexibility, stability, and mechanical strength, making it suitable for further pharmacological evaluation.

INTRODUCTION

Inflammation is a complex biological response of vascularized tissues to harmful stimuli such as infection, injury, or chemical irritation. It represents the body's natural defense mechanism but can lead to chronic diseases when uncontrolled, including rheumatoid arthritis, cardiovascular disorders, and autoimmune conditions. Conventional anti-inflammatory agents such as non-steroidal anti-inflammatory drugs (NSAIDs) are effective but often cause gastrointestinal and renal side effects upon prolonged use. This limitation has encouraged the exploration of natural bioactive compounds as safer alternatives for inflammation management (Munda et al., 2018; Wang et al., 2021).

Kaempferia galanga L., commonly known as galangal, is a medicinal plant widely distributed in tropical Asia and traditionally used to relieve pain, inflammation, and respiratory disorders. Its major bioactive constituent, ethyl para-methoxycinnamate (EPMC), exhibits potent anti-inflammatory,

doi : https://.....

analgesic, and antioxidant activities (Munda et al., 2018; Wang et al., 2021). However, the oral administration of EPMC is limited by poor water solubility and extensive first-pass metabolism, leading to low systemic bioavailability (Samodra & Febrina, 2020). To overcome these limitations, transdermal delivery systems offer a promising route by allowing controlled release, by passing hepatic metabolism, and maintaining stable plasma concentrations.

Previous studies have explored the topical delivery of K. galanga extracts or pure EPMC isolates using conventional formulations such as creams or gels. However, the use of crude extracts often faces challenges related to the presence of impurities that hinder drug release, while utilizing pure EPMC requires costly and time-consuming isolation processes. The semi-polar fraction offers a strategic compromise, providing a highly concentrated EPMC content with better cost-effectiveness. Despite this advantage, there is a lack of comprehensive studies evaluating the compatibility and formulation optimization of the semi-polar fraction of K. galanga for a transdermal patch matrix, particularly regarding how varying HPMC concentrations affect its physical and mechanical properties. Transdermal patches are polymeric matrices that deliver drugs across the skin in a controlled manner, improving patient compliance and reducing systemic side effects. Hydroxypropyl methylcellulose (HPMC) is one of the most widely used polymers in patch formulation due to its biocompatibility, flexibility, and capacity to modulate drug diffusion. HPMC is superior in terms of flexibility and user comfort and is less likely to cause skin irritation (Guarve & Kriplani, 2021).

Therefore, the present study aimed to formulate transdermal patches containing the semi-polar fraction of K. galanga rhizomes and to determine the optimum HPMC concentration (0.5%, 1.0%, and 1.5%). Specifically, this study evaluates the impact of these polymer variations on critical physical properties—including moisture content, mechanical strength (folding endurance), and pH—to establish a highly stable and skin-compatible patch formulation for future pharmacological applications. The novelty of this research lies in the utilization of the enriched semi-polar fraction of K. galanga rather than its crude extract or pure isolate, and the specific optimization of HPMC concentrations tailored to accommodate the unique physicochemical characteristics of this fraction within a transdermal matrix.

RESEARCH METHODS

Materials

The materials used in this study included fresh rhizomes of Kaempferia galanga L. obtained from Ciomas, Bogor, Indonesia; ethanol 96% as extraction solvent; n-hexane and ethyl acetate as fractionation solvents; hydroxypropyl methylcellulose (HPMC) as film-forming polymer; propylene glycol as plasticizer; methyl paraben as preservative; and distilled water as solvent. All reagents and solvents used were of analytical grade and obtained from PT Brataco Chemical, Bogor, Indonesia.

Preparation of Extract

The rhizomes were thoroughly washed, sliced, and air-dried at room temperature for seven days until constant weight was achieved. The dried materials were ground into fine powder using a mechanical grinder. Maceration was carried out using ethanol 96% at a ratio of 1:10 (w/v) for three consecutive 24-hour periods with occasional stirring to enhance compound diffusion. After each cycle, the filtrate was separated and combined before being concentrated under reduced pressure using a rotary evaporator at 45°C.

The resulting ethanolic extract was a viscous brownish liquid, which was further subjected to solvent partitioning to isolate the semi-polar fraction. Fractionation was performed sequentially with n-hexane and ethyl acetate in a separating funnel. The ethyl acetate layer, containing semi-polar compounds, was collected and concentrated again under reduced pressure to yield the semi-polar extract fraction (Samodra & Febrina, 2020).

Identification of major bioactive constituents was carried out using Gas Chromatography–Mass Spectrometry (GC–MS). The chromatographic peaks were compared with spectral data from the NIST library to confirm the presence of ethyl para-methoxycinnamate (EPMC) as the dominant component. This compound was chosen as a chemical marker due to its well-documented anti-inflammatory activity and relevance to transdermal delivery research (Wahyuni et al., 2021).

Formulation

Transdermal patches were prepared by the solvent casting technique. Accurately weighed quantities of HPMC (0.5%, 1%, and 1.5%) were dispersed in 50 mL of distilled water under continuous stirring and allowed to swell overnight. The semi-polar fraction of K. galanga extract (0.6% w/w) was dissolved in ethanol and added to the polymer dispersion along with propylene glycol (1 mL) and methyl paraben (0.05 g). The mixture was stirred until a homogeneous solution was formed.

The resulting viscous solution was poured into glass molds (9 × 9 cm) and allowed to dry at 60°C for 72 hours in a hot air oven. After drying, the films were carefully peeled off, wrapped in aluminum foil, and stored in desiccators at room temperature until further evaluation. The resulting patches were coded as F1 (0.5% HPMC), F2 (1.0% HPMC), and F3 (1.5% HPMC) (Andini et al., 2024).

This solvent-casting approach ensures uniform dispersion of the active compound and reproducibility in patch thickness and drug distribution. The use of HPMC concentration variations allowed the study of polymer effects on physical parameters such as mechanical strength, moisture retention, and film pH. All procedures were conducted at controlled room temperature (25 ± 2°C) and humidity (60 ± 5%) to maintain formulation consistency.

Evaluation of Physical Properties

The prepared patches were evaluated for six key physical parameters—organoleptic characteristics, weight uniformity, thickness, folding endurance, surface pH, and moisture content—to assess their

quality, consistency, and suitability for transdermal application. All tests were performed in triplicate (n = 3), and the mean ± SD was reported.

Organoleptic Evaluation

Organoleptic examination was carried out visually without any aids, including the color, odor, and shape of the resulting patch preparation (Andini et al., 2024).

Weight Uniformity

Weight uniformity testing was performed by weighing 10 randomly selected patches from each formula. The average weight of the resulting patches was then calculated, with a tolerance of no more than ±5% (Andini et al., 2024).

Thickness Measurement

Patch thickness testing was measured using a micrometer screw gauge with an accuracy of 0.01 mm. Patch thickness was measured at three points on each patch, then the average patch thickness was calculated. The variation in thickness between points on a single patch should not exceed ±5% of the average thickness. [7].

Folding Endurance

Folding resistance testing is performed by folding the patch repeatedly in the same position until it breaks. The number of folds is considered the folding resistance value. A standard folding resistance value is >200 folds (Andini et al., 2024).

Surface pH

The pH of the patch preparation was measured using a pH meter. The patch solution was soaked in 10 mL of distilled water for 2 hours. The electrode was then dipped into a beaker containing the patch solution. The acceptable pH range for non-irritating skin is 4-7 (Andini et al., 2024).

Moisture Content

Determination of moisture content in Patch preparations is carried out to ensure the physical stability and quality of the preparation, as well as to avoid degradation of active ingredients due to excessive moisture. Moisture content is measured using a moisture analyzer. The test is carried out by turning on the device and opening the cover. Then, one sheet of Patch is placed on the device. It is then closed and programmed to heat to a temperature of 105°C. During the heating process, the device automatically calculates the moisture content based on the change in mass. The final measurement result is displayed as a moisture percentage on the digital moisture analyzer screen. The use of this method is considered accurate and efficient in determining the moisture content of solid preparations such as Patches with a range of 3%-7% (Amalia et al., 2023).

RESULTS

Analysis of the compounds in isolates was performed using Gas Chromatography–Mass Spectrometry (GC–MS) shows that isolates contain 18 compounds, as shown in Table 1. Identification of the major compound (EPMC) was further supported by the mass spectral analysis obtained from the GC–MS instrument (Figure 1), supported by a match score of 98.8%, indicating an excellent correspondence between the sample and reference spectra. The patches were successfully made (Figure 2) and tested (Table 2).

Table 1. Results of Identified Compounds in EPMC Isolates

No	Retention Time (minute)	Compound names	Molecule	*Matech Score*	Area (%)
1	2.2118	*Cyclohexane*	C_6H_{12}	98.3	2.89
2	2.4492	*Propanoic acid, ethyl ester*	$C_5H_{10}O_2$	86.6	0.02
3	3.0190	*Toluene*	C_7H_8	96.6	0.06
4	13.3347	*2-Propenoic acid, 3-phenyl-, ethyl ester (E)-*	$C_{11}H_{12}O_2$	97.1	3.40
5	13.6077	*(1R,2S,6S,7S,8S)-8-Isopropyl-1-methyl-3-methylenetricyclo[4.4.0.02,7]decane*	$C_{15}H_{24}$	81.9	0.02
6	13.6908	*Pentadecane*	$C_{15}H_{32}$	89.5	0.06
7	13.9816	*Octahydro-naphthalene derivative*	$C_{15}H_{24}$	87.6	0.04
8	14.5930	*1,5-Cyclodecadiene, 1,5-dimethyl-8-(1-methylethylidene)- (E,E)*	$C_{15}H_{24}$	87.2	0.03
9	14.7888	*Diethyl Phthalate*	$C_{12}H_{14}O_4$	86.0	0.10
10	15.2399	*4a(2H)-Naphthalenol derivative*	$C_{15}H_{26}O$	86.1	0.03
11	15.5070	*Cyclopentaneacetic acid, 3-oxo-2-pentyl-, methyl ester*	$C_{13}H_{22}O_3$	95.5	0.28
12	15.7444	*Amberonne (isomer 2)*	$C_{16}H_{26}O$	83.8	0.12
13	15.8335	*Cyclohexanol derivative*	$C_{15}H_{26}O$	83.4	0.93
14	**16.7950**	***Ethyl (E)-p-methoxycinnamate***	$\mathbf{C_{12}H_{14}O_3}$	**98.8**	**91.55**
15	17.7268	*Cyclopenta[g]-2-benzopyran, hexamethyl derivative*	$C_{18}H_{26}O$	93.3	0.20
16	18.4510	*Hexadecanoic acid, methyl ester*	$C_{17}H_{34}O_2$	87.5	0.10
17	18.5281	*Benzenepropanoic acid derivative*	$C_{18}H_{28}O_3$	85.6	0.05
18	20.1010	*9,12-Octadecadienoic acid, methyl ester*	$C_{19}H_{34}O_2$	82.7	0.04

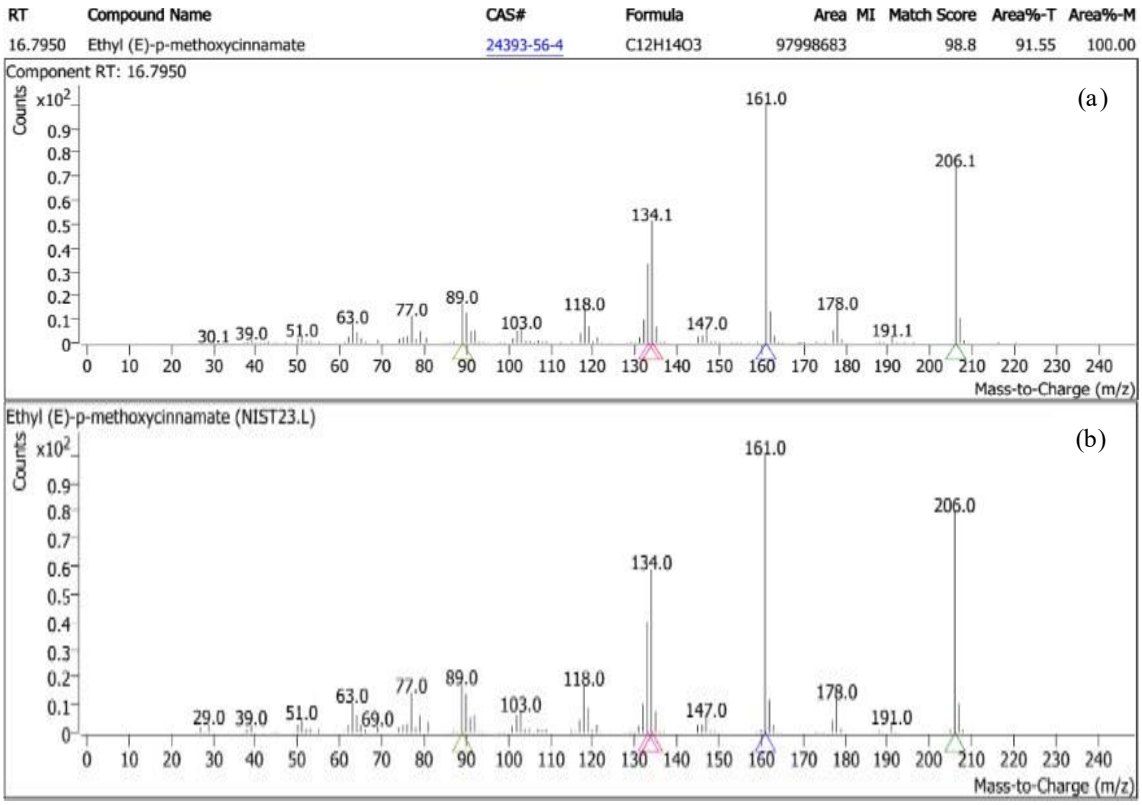

Figure 1. Mass spectrum of sample results (a), Literature mass spectrum (NIST) for EPMC

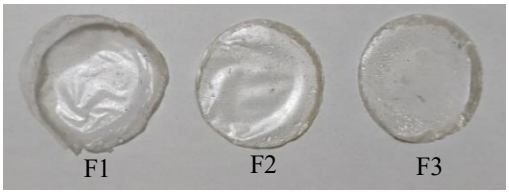

Figure 2. Transdermal Patch F1(0,5% HPMC; F2 (1% HPMC); F3 (1,5% HPMC)

Table 2. Physical Evaluation Results of Transdermal Patch Containing Semi-Polar Fraction of Kaempferia galanga L. Rhizomes

Parameters	Formula 1 (0.5% HPMC)	Formula 2 (1% HPMC)	Formula 3 (1.5% HPMC)	Requirement (Reference)
Organoleptic	Transparent, flexible, smooth surface, characteristic odor of galanga	Transparent, flexible, smooth surface, characteristic odor	Transparent, slightly rigid, smooth surface, characteristic odor	Should be clear, uniform, and flexible [9]
Water content (% ± SD)	4.52 ± 0.06^{b}	4.13 ± 0.04^{a}	3.77 ± 0.05^{c}	< 10% [9]
pH (± SD)	6.81 ± 0.03^{a}	6.85 ± 0.02^{a}	6.88 ± 0.02^{a}	5 – 9 (Bakhrushina et al., 2025)

Weight uniformity (g ± SD)	0.712 ± 0.002[b]	0.728 ± 0.001[b]	0.743 ± 0.001[a]	Variation < 5% [9]
Thickness (mm ± SD)	0.295 ± 0.002[b]	0.301 ± 0.001[a]	0.305 ± 0.002[a]	0.02 – 0.10 mm [11]
Folding endurance (times ± SD)	326 ± 4.15[c]	341 ± 5.02[b]	364 ± 3.45[a]	> 200 times [11]

DISCUSSION

Analysis of the compounds within the fractions was performed using Gas Chromatography–Mass Spectrometry (GC–MS), a highly sensitive and selective analytical technique for the separation and identification of volatile and semi-volatile compounds in complex mixtures. In this study, an HP-5MS capillary column (30 m × 0.25 mm × 0.25 µm), composed of low-polarity polydimethylsiloxane, was employed, making it suitable for analyzing aromatic compounds, esters, and terpenoid classes commonly found in plant secondary metabolites. The oven temperature was programmed to begin at 60 °C for 2 minutes, followed by an increase of 10 °C per minute until reaching 280 °C. This temperature-gradient program is designed to separate compounds across a wide range of volatilities. Low–molecular-weight compounds such as toluene (RT: 3.01 minutes) eluted earlier, whereas heavier compounds such as EPMC (RT: 16.795 minutes) eluted at higher temperatures (Wahyuni et al., 2021). This ensures that each compound exhibits a unique, non-overlapping retention time, thereby providing optimal chromatographic resolution, as presented in Table 1.

Following chromatographic separation, detection was carried out using mass spectrometry operating under electron ionization (EI, 70 eV), which generates molecular fragments characteristic of each compound. Each peak was identified based on its mass spectrum and subsequently matched against the NIST library. The match score was used to indicate the degree of similarity, with values ≥95% considered highly reliable (Karam et al., 2026); for example, EPMC yielded a score of 98.8%.

Identification of the major compound in the fraction was further supported by the mass spectral analysis obtained from the GC–MS instrument. As shown in Figure 1, the sample spectrum exhibits a dominant peak at a mass-to-charge ratio (m/z) of 206.1, corresponding to the intact molecular ion (M^+) of EPMC. Other notable fragments appear at m/z 161.0, 147.0, 134.1, 118.0, and 178.0. The fragment at m/z 161.0 results from cleavage of the ester moiety, while the peaks at m/z 147.0 and 134.1 are associated with the aromatic ring bearing the methoxy substituent (Abiedalla & Clark, 2023).

Comparison with the NIST reference spectrum (Figure 1) shows that all major peaks in the experimental spectrum are likewise present in the library spectrum, with highly similar positions and relative intensities. This congruence in fragmentation patterns, supported by a match score of 98.8%, indicates an excellent correspondence between the sample and reference spectra. It further suggests that

the compound not only possesses the expected molecular weight and structure but also undergoes identical fragmentation under 70 eV EI conditions.

The spectrum therefore provides strong analytical justification that the predominant compound, accounting for 91.55% of the relative peak area, is Ethyl (E)-p-methoxycinnamate. The presence of characteristic peaks and their close agreement with the reference spectrum reinforces the validity of the identification and minimizes the likelihood of misinterpretation due to contaminants or peak overlap. Consequently, from an analytical standpoint, the identification of EPMC in this fraction is highly robust and supports the conclusion that the isolation process successfully enriched the major bioactive constituent.

All three formulations produced clear, smooth, and transparent films, indicating that HPMC effectively formed a homogeneous matrix. The films had a characteristic odor of Kaempferia galanga, confirming the incorporation of the semi-polar fraction. Formulas 1 and 2 produced highly flexible films, while Formula 3 appeared slightly more rigid due to the higher polymer concentration, which increases matrix density. The overall appearance was in accordance with the BPOM criteria that transdermal films should be uniform, clear, and non-sticky (Figure 2). The slight increase in rigidity observed in Formula 3 is consistent with previous studies showing that high HPMC concentrations lead to denser hydrogen bonding between polymer chains, thus reducing elasticity (Guarve & Kriplani, 2021). Such changes can be beneficial in improving the patch's mechanical strength and minimizing deformation during storage or application. However, excessive rigidity might affect patient comfort or skin adhesion (Ishimura et al., 2025).

Overall, the organoleptic evaluation demonstrated that variations in HPMC concentration had a perceptible influence on film flexibility and smoothness but did not compromise the physical acceptability of the patches. The results indicate that all formulations possess desirable characteristics for transdermal delivery, particularly Formula 2, which balanced flexibility and firmness effectively, that optimal polymer concentration yields films with ideal tactile and visual properties (Lakshmi et al., 2011).

Water content affects film stability, microbial resistance, and mechanical flexibility. The measured values decreased from 4.52% in F1 to 3.77% in F3, showing an inverse relationship with HPMC concentration. The reduction results from the denser polymer matrix formed at higher concentrations, which limits the film's capacity to retain moisture (Kurek et al., 2026). Low water content is beneficial because it prevents microbial growth and enhances product shelf life. All formulations met the BPOM requirement of <10%, demonstrating proper drying and solvent removal during preparation. Moreover, the moisture levels observed in this study correspond well with other reports on cellulose-based transdermal systems (Lakshmi et al., 2011). However, an overly dry patch could become brittle. F3 maintained an optimal balance, showing low water content yet good flexibility. These characteristics

make it a promising formulation for further drug release and stability testing. The results highlight that careful adjustment of polymer concentration can optimize both physical and stability characteristics of transdermal patches.

The pH values of all formulations ranged between 6.81 and 6.88, which aligns with the physiological pH range of human skin (4.5–7.5). This ensures that the patches are non-irritating and compatible for topical use (Amalia et al., 2023). The minor differences among formulations indicate that variations in HPMC concentration did not significantly alter the acidity of the matrix. Maintaining a neutral pH is crucial to preserving drug stability, particularly for EPMC, which may undergo hydrolysis in acidic or basic environments. HPMC provides buffering capacity by trapping residual ions within the gel matrix, thereby maintaining an optimal environment for the active ingredient (Ozon et al., 2025). These findings confirm that all formulations meet pharmacopeial standards and are safe for dermal application. The slight increase in pH observed with higher HPMC concentration may be attributed to the polymer's hydroxyl groups that slightly neutralize the medium (Kesharwani et al., 2015). Overall, all formulations demonstrated excellent pH stability and skin compatibility.

Weight uniformity testing ensures consistent distribution of active ingredients across the patch surface. All formulations showed minimal variation (<5%), indicating good homogeneity of the polymer–drug mixture. The mean weights ranged from 0.712 to 0.743 g, with F3 being the heaviest due to its higher HPMC content, which increases the solid fraction per unit area. This uniformity complies with USP standards (The United States Pharmacopeial Convention, 2023) and confirms that the casting and drying processes were consistent. Increased polymer concentration is directly proportional to solution viscosity, which can result in a thicker and heavier matrix after solvent evaporation (Tundisi et al., 2021). The data demonstrate that despite viscosity differences, the mixing process achieved uniform dispersion of the EPMC-containing fraction. This ensures dose reproducibility—an essential factor in maintaining therapeutic efficacy in transdermal systems.

Comparative analysis with related studies suggests that consistent weight across formulations is indicative of good polymer-drug compatibility and stable film formation. These results validate that the use of HPMC as a primary film former maintains weight uniformity even at varying concentrations, highlighting its reliability for controlled-release patch formulations (Lakshmi et al., 2011; Samodra & Febrina, 2020).

Patch thickness is a critical parameter influencing both mechanical behavior and drug diffusion. Patch matrix that is thinner will be preferred because it is more comfortable to use and better patch appearance (Ermawati & Kartikasari, 2020). As shown in Table 2, the thickness of the three formulations increased slightly with rising hydroxypropyl methylcellulose (HPMC) concentrations, ranging from 0.295 mm (F1) to 0.305 mm (F3). This increase corresponds to the higher viscosity of the polymer casting solution, which yields a greater solid residue following solvent evaporation. Notably, all

formulations fell within the acceptable thickness range for transdermal matrices (0.10–0.50 mm), consistent with parameters established by Andini et al., (2024). A denser polymer network, as observed in F3, provides a stable and uniform structure that supports the sustained retention of the active compound within the film matrix. However, such density can also restrict internal diffusion pathways, potentially slowing the release and subsequent permeation of the ethyl p-methoxycinnamate (EPMC) fraction across the skin barrier (Oktavia R. Adianingsih et al., 2025). Consequently, optimizing patch thickness is vital to balance structural stability with controlled release efficiency. The obtained results confirm that variations in HPMC concentration can finely tune patch dimensions without inducing surface irregularities or cracks, demonstrating that appropriate polymer viscosity ensures smooth casting and consistent thickness distribution. Therefore, F3 exhibited an ideal structural configuration, providing robust mechanical strength while maintaining the requisite flexibility for skin adherence (Guarve & Kriplani, 2021).

Folding endurance assesses flexibility and resistance to mechanical stress during application. All patches showed values exceeding 200 folds, the minimum requirement for acceptable mechanical performance (Andini et al., 2024). F3 achieved the highest endurance (364 folds), indicating improved tensile resilience with increased HPMC concentration. This enhancement occurs because higher polymer content promotes stronger intermolecular hydrogen bonding, improving the film's structural integrity. Such interactions prevent crack formation under repetitive bending stress (Tundisi et al., 2021). In contrast, formulations with lower polymer levels may exhibit micro-fractures due to weaker interchain cohesion, reducing their physical durability. In line with previous findings, increased HPMC content enhances elasticity by forming a cohesive gel network. Therefore, while F3 had the best endurance, all formulations demonstrated mechanical properties that meet industrial expectations for transdermal delivery systems, indicating that HPMC is an efficient and reliable film-forming polymer (Lakshmi et al., 2011).

CONCLUSION

This study demonstrated that variations in HPMC concentration significantly affect the physical properties of transdermal patches containing the semi-polar fraction of Kaempferia galanga L. rhizomes. The 1.5% HPMC formulation showed the best mechanical strength, flexibility, pH, and moisture balance, meeting pharmaceutical quality standards. These findings suggest that HPMC is an effective polymer for herbal-based transdermal systems, and the developed patch has strong potential for further in vitro and in vivo evaluation.

ACKNOWLEDGEMENTS

The author is grateful to LPPM Pakuan University for the funding of this research through the research grant.

REFERENCES

Abiedalla, Y., & Clark, C. R. (2023). Electron ionization fragmentation studies for a series of 4-methoxymethylene benzoate esters. *Rapid Communications in Mass Spectrometry*, *37*(24). https://doi.org/10.1002/rcm.9654

Amalia, A., Nining, N., & Adiningsih, J. Y. (2023). SIFAT FISIKOKIMIA DAN LAJU DIFUSI PATCH TRANSDERMAL DISPERSI PADAT MELOKSIKAM YANG MENGGUNAKAN NATRIUM LAURIL SULFAT SEBAGAI PENINGKAT PENETRASI. *Jurnal Farmasi Udayana*, 36. https://doi.org/10.24843/jfu.2022.v11.i02.p01

Andini, S., Rustiani, E., & Lathifah, U. (2024). Formulation and In-Vitro Penetration Test of Ketoprofen Patch with Addition Aloe vera Powder (Aloe vera L.) Bioenhancer. *FITOFARMAKA: JURNAL ILMIAH FARMASI*, *14*(1), 51–58. https://doi.org/10.33751/jf.v14i1.9874

Bakhrushina, E. O., Shumkova, M. M., Avdonina, Y. V., Ananian, A. A., Babazadeh, M., Pouya, G., Grikh, V. V., Zubareva, I. M., Kosenkova, S. I., Krasnyuk, I. I., & Krasnyuk, I. I. (2025). Transdermal Drug Delivery Systems: Methods for Enhancing Skin Permeability and Their Evaluation. *Pharmaceutics*, *17*(7), 936. https://doi.org/10.3390/pharmaceutics17070936

Ermawati, D. E., & Kartikasari, G. (2020). The Effect of Combination of Hydroxypropylmethylcellulose and Carboxymethylcellulose Sodium Polymers to The Physical Properties of Celery (Apium graveolens L.) Ethanolic Extract Patch. *Majalah Farmaseutik*, *16*(2), 146. https://doi.org/10.22146/farmaseutik.v16i2.50358

Guarve, K., & Kriplani, P. (2021). HPMC- A Marvel Polymer for Pharmaceutical Industry-Patent Review. *Recent Advances in Drug Delivery and Formulation*, *15*(1), 46–58. https://doi.org/10.2174/1872211314666210604120619

Ishimura, A., Tabayashi, Hi., & Inoue, M. (2025). Clinical Implications of Mechanical and Adhesive Differences Between Branded and Generic Tulobuterol Patches in Asthma Management. *Cureus*. https://doi.org/10.7759/cureus.96638

Karam, A., Ramzy, A., Abdelmoneim, T. K., Mokhtar, M., Youssef, N. A., Osama, A., Sabar, N., & Magdeldin, S. (2026). STRIKER: a spectral metadata repairing tool for expanding the comprehensiveness of spectral libraries. *Journal of Cheminformatics*, *18*(1), 26. https://doi.org/10.1186/s13321-026-01150-4

Kesharwani, R., Patel, D. K., Sachan, A., Kumar, V., & Mazumdar, B. (2015). Ethosomes: A Novel Approach for Transdermal and Topical Drug Delivery. *Research Journal of Topical and Cosmetic Sciences*, *6*(1), 15. https://doi.org/10.5958/2321-5844.2015.00003.5

Kurek, M., Soldo, A., Babić, P., Benbettaieb, N., Debeaufort, F., & Sokač Cvetnić, T. (2026). The Development and Characterization of Biobased Film Formulations Made of Chitosan, Gelatine, and Gum Arabic with the Addition of Lemon Balm (Melissa officinalis L.) Extract as a Novel Food Packaging. *Molecules*, *31*(10), 1582. https://doi.org/10.3390/molecules31101582

Lakshmi, P. K., Sridharan, A., & Sreekanth, J. (2011). Formulation development of fast releasing oral thin films of levocetrizine dihydrochloride with Eudragit®Epo and optimization through Taguchi orthogonal experimental design. *Asian Journal of Pharmaceutics*, *5*(2), 84. https://doi.org/10.4103/0973-8398.84548

Munda, S., Saikia, P., & Lal, M. (2018). Chemical composition and biological activity of essential oil of*Kaempferia galanga*: a review. *Journal of Essential Oil Research*, *30*(5), 303–308. https://doi.org/10.1080/10412905.2018.1486240

Oktavia R. Adianingsih, Kadek S. Maesayani, Oktavia E. Puspita, & Bachtiar R. P. Ihsan. (2025). Formulation of Transfersome Containing Kaempferia galanga for Transdermal Patch Application. *Tropical Journal of Natural Product Research*, *9*(8). https://doi.org/10.26538/tjnpr/v9i8.51

Ozon, E. A., Burloiu, A. M., Musuc, A. M., Manda, G., Anuta, V., Dinu-Pîrvu, C. E., Lupuliasa, D., Neagoe, I. V., Anastasescu, M., Socoteanu, R. P., Atkinson, I., Mitran, R.-A., Culita, D. C., &

Boscencu, R. (2025). Cellulose-Derived Gels for Topical Delivery: HPMC as a Functional Matrix for Porphyrinic Photosensitizers. *Gels*, *11*(10), 824. https://doi.org/10.3390/gels11100824

Samodra, G., & Febrina, D. (2020). Anti-Inflammatory Effects of Kaempferia galanga L. Rhizome Extract in Carrageenan-Induced Female Rats. *Proceedings of the 1st International Conference on Community Health (ICCH 2019)*. https://doi.org/10.2991/ahsr.k.200204.004

The United State Pharmacopeial Convention. (2023). Uniformity of Dosage Units. In *The United States Pharmacopeia (USP)* (46th ed., 905).

Tundisi, L. L., Mostaço, G. B., Carricondo, P. C., & Petri, D. F. S. (2021). Hydroxypropyl methylcellulose: Physicochemical properties and ocular drug delivery formulations. *European Journal of Pharmaceutical Sciences*, *159*, 105736. https://doi.org/10.1016/j.ejps.2021.105736

Wahyuni, I. S., Sufiawati, I., Nittayananta, W., & Levita, J. (2021). Identification of Ethyl Para-Methoxycinnamate and Kaempferol in the Ethanol Extract of <i>Kaempferia galanga </i>L. Rhizome as Biomaterial for Drug Candidate Using Spectrophotometric and Chromatographic Analysis. *Materials Science Forum*, *1028*, 371–376. https://doi.org/10.4028/www.scientific.net/msf.1028.371

Wang, S.-Y., Zhao, H., Xu, H.-T., Han, X.-D., Wu, Y.-S., Xu, F.-F., Yang, X.-B., Göransson, U., & Liu, B. (2021). Kaempferia galanga L.: Progresses in Phytochemistry, Pharmacology, Toxicology and Ethnomedicinal Uses. *Frontiers in Pharmacology*, *12*. https://doi.org/10.3389/fphar.2021.675350