

Formulation Development and Characterization of Novel *Anti-Psoriatic* Cream for Topical Drug Delivery

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www.jrasb.com || Vol. 4 No. 4 (2025): August Issue

Received: 19-07-2025

Revised: 23-07-2025

Accepted: 28-07-2025

ABSTRACT

A systematic approach was employed to formulate four different cream bases (F1 to F4) using various emollients, humectants, and penetration enhancers to assess their impact on physicochemical properties, skin compatibility, drug release behavior, and stability. Four different cream formulation was prepared using oil-in-water (O/W) or anhydrous cream technique, depending on the base type used like anhydrous base (F1), lanolin base (F2), Silicone base (F3) and Glycerine rich base (F4). All formulations were physically uniform with smooth textures and no evidence of phase separation. Among them, F3 exhibited the best uniformity, likely due to the inclusion of dimethicone and triglycerides, which improve texture and spread. pH of all batch creams had pH values ranging from 5.5 to 5.8, which is within the physiologically acceptable range for topical application. Spreadability values ranged from 6.8 to 8.6 g·cm/s, with F3 showing the highest spreadability. Cream consistency ranged from 46,500 to 58,000 cP, with F1 having the highest viscosity due to its wax-heavy base. F3 showed the lowest viscosity, drug release. F3 achieved the highest cumulative permeation of Mahonia aquifolium ($52.7 \pm 1.8 \mu\text{g}/\text{cm}^2$), highlighting the effectiveness of its base in facilitating skin penetration. F4 followed closely ($46.5 \pm 1.6 \mu\text{g}/\text{cm}^2$), while F1 showed the least permeation, attributed to its dense occlusive base. The optimized formulation, F3, underwent accelerated stability testing at 40°C for 3 months under ICH guidelines. The formulation was monitored for changes in pH, viscosity, spreadability, permeation, extrudability, and homogeneity. Drug release efficiency was maintained with negligible decline (52.7% to 51.8%), indicating no compromise in performance after storage. Extrudability remained consistent, indicating maintained usability.

Keywords- Mahonia Aquifolium, Indigo naturalis, Polyherbal cream, Psoriasis.

I. INTRODUCTION

Psoriasis is an immune-mediated inflammatory disease with unknown etiology that may be associated with the defect in proliferation and differentiation of keratinocytes associated with inflammatory cell infiltration particularly consisting T-lymphocytes, macrophages, and neutrophils. Psoriasis affects 1–3% of the adult population with various extra cutaneous manifestations. Psoriasis affects both males and females, with earlier onset in females and those with a family history. Its age of onset shows a bimodal distribution with peaks at 30–39 years and 60–69 years in men, and 10 years earlier in women. An estimated 60 million people have psoriasis worldwide, with country-specific prevalence varying between 0.05% of general

population in Taiwan and 1.88% in Australia.^{3,4} It is more common in high income areas and those with older populations.³ In the UK, it affects 1.52% of the general population.

Poly-herbal medicine refers to the therapeutic use of a combination of two or more plant-based extracts in a single formulation, designed to exert a synergistic effect for enhanced efficacy. In the management of chronic inflammatory skin disorders such as psoriasis, poly-herbal approaches are gaining popularity due to their multi-targeted actions, fewer side effects, and natural origin. Psoriasis, being an immune-mediated, relapsing condition, often requires long-term treatment, and herbal alternatives offer a supportive or adjunctive option, especially for patients seeking holistic or complementary therapies.

Several medicinal plants have demonstrated anti-psoriatic potential and are used in poly-herbal formulations: Mahonia Aquifolium (Oregon grape): Contains bebeerine and alkaloids with anti-inflammatory and ant proliferative effects. It has shown promise in reducing psoriatic lesion severity. Indigo naturalis (Qing Dai): Rich in indirubin, it modulates IL-17 and keratinocyte proliferation. Clinical trials have demonstrated its efficacy in topical formulations. Aloe vera: A natural moisturizer with anti-inflammatory, antibacterial, and wound healing properties. It soothes itching and promotes skin regeneration. Curcuma longa (Turmeric): Its active constituent curcumin exhibits potent anti- inflammatory and antioxidant effects by inhibiting NF-κB and cytokine pathways. Azadirachta indica (Neem): Used for its antiseptic, antifungal, and immunomodulatory actions. Rubia cordifolia, Glycyrrhiza glabra, and Wrightia tinctoria are also widely used in Ayurvedic formulations for psoriasis due to their skin-calming and detoxifying effects.

II. MATERIALS AND METHOD

Materials-

Mahonia Aquifolium Extract, Indigo Naturalis Extract was obtained from Yucca Chem, Mumbai. White Soft Paraffin & Propylene glycol were purchased from S.D. Fine Chem. Ltd, Mumbai, All other chemicals and solvents are analytical grade.

Method

UV Spectroscopy:

A stock solution of Mahonia aquifolium extract was prepared by using water. Then UV Spectrum was scanned in the range 200-400nm by using Shimadzu 1601.

Formulation of Anti Psoriasis Cream:

The preparation of the above cream formulations involves the oil-in-water (O/W) or anhydrous cream technique, depending on the base type used like anhydrous base (F1), lanolin base(F2), Silicone base (F3) and Glycerine rich base (F4). The general method is adapted for each specific formulation base as follows.

Preparation of Oil Phase:

For each formulation (F1–F4), the oil phase was prepared by weighing and melting the oil-

soluble ingredients such as white soft paraffin, yellow beeswax, lanolin, coconut oil, mineral oil, isopropyl myristate, capric triglyceride, dimethicone, and cetostearyl alcohol in a beaker. These were heated gently in a water bath at 70–75°C with continuous stirring until a homogenous clear phase was obtained. In the case of F3 (Silicone Base), dimethicone were incorporated carefully without overheating.

Preparation of Aqueous Phase:

In a separate beaker, the water-soluble components such as glycerin, propylene glycol, and methyl paraben (dissolved in warm water) were mixed and heated to the same temperature (70–75°C) to ensure proper blending. The emulsifier Span 80 was added to either the oil or aqueous phase depending on solubility to stabilize the emulsion.

Emulsion Formation:

The aqueous phase was gradually added to the oil phase with continuous stirring using a homogenizer or overhead stirrer. Stirring was maintained for 15–20 minutes until a uniform emulsion was formed. For the anhydrous formulation (F1), the procedure involved only the mixing of oil-based components without water addition.

Cooling and Active Incorporation:

As the emulsion cooled to about 40–45°C, the active herbal extracts Mahonia aquifolium (5%), Indigo naturalis (2.5%), and Aloe vera powder were incorporated slowly with constant stirring to ensure even distribution and avoid degradation from high heat. For powder extracts, a small amount of propylene glycol or glycerin was used to pre-disperse before adding.

Final Volume Adjustment:

After complete mixing and cooling to room temperature (~25°C), purified water was added q.s. to 100 g to adjust the final weight of each formulation. Stirring was continued gently to maintain homogeneity and avoid aeration.

Packaging and Storage:

The finished creams were transferred into airtight container or collapsible tubes, and stored in a cool, dry place for further evaluation. The details for the formulation of cream were shown in table 1.

Table 1: Composition of Cream Formulation

Ingredients (% w/w)	F1	F2	F3	F4
Mahonia Aquifolium Extract	5	5	5	5
Indigo Naturalis Extract	2.5	2.5	2.5	2.5
Aloe Vera Powder	1	1	1	1
White Soft Paraffin	30	15	—	—
Yellow Beeswax	10	—	—	—
Lanolin (Anhydrous)	5	10	—	—
Coconut Oil	5	—	—	—
Mineral Oil	—	10	—	10

Isopropyl Myristate	–	–	5	–
Capric Triglyceride	–	–	5	–
Dimethicone	–	–	4	–
Cetostearyl Alcohol	–	–	–	3
Glycerin	–	–	2	6
Propylene Glycol	–	3.0	3.0	3
Span 80	2	2	2	2
Methyl Paraben	0.5	0.5	0.5	0.5
Purified Water	q.s. to 100	q.s. to 100	q.s. to 100	q.s. to 100

III. EVALUATION OF CREAM

Homogeneity

All developed Creams formulations were tested for homogeneity by visual inspection after the Creams have been set in the container. They were tested for their appearance and presence of any aggregates.

pH

10gm Cream was accurately weighed and dispersed in 100 ml purified water. The pH of the dispersion was measured using digital pH meter.

Spreadability

It is one of the criteria for a topical formulation to meet the ideal qualities is that it should possess good spreadability. The spreadability of the prepared transdermal formulations was measured using spreadability test. It helps to determine the extent of the area that the formulation could freely spread over the affected part of the skin after being applied. The therapeutic efficacy of a formulation also depends upon its spreading value. To determine the spreadability of formulation, 1 g of cream was placed within a circle of 1 cm diameter which was pre-marked on a glass plate of 20 × 20 cm, over which a second glass plate was placed. A weight of 500 g was allowed to rest on the upper glass plate for 5 min. The increase in the diameter due to Cream spreading was noted and it considered as spreading values.

Extrudability

To determine extrudability a closed collapsible tube containing 20 g of Cream formulation was pressed firmly at the crimped end and a clamp was applied to prevent any roll back. The cap was removed and the Cream was extruded. The amount of the extruded Cream was collected and weighed. The percentage of the extruded Cream was calculated. [52] The following parameter was set for extrudability results

- >90% extrudability: Excellent,
- >80% extrudability: Good,
- >70% extrudability: Fair.

Viscosity

The viscosity of the prepared cream formulations was determined using a Brookfield Viscometer, which measures the resistance of the cream to flow under applied shear stress. (Brookfield Engineering Laboratories, USA). The test was carried out at room temperature ($25 \pm 2^\circ\text{C}$) using an

appropriate spindle, generally Spindle No. 6. A sufficient quantity (approximately 50 g) of the cream sample was transferred into a clean, dry beaker of suitable diameter (usually 100 mL capacity) to ensure uniform contact with the spindle. The spindle was then immersed vertically into the cream without touching the bottom or sides of the container. Care was taken to avoid the inclusion of air bubbles during sample transfer and spindle immersion, as this could affect the accuracy of the reading. The instrument was set at a standard rotational speed, typically 10 rpm, and the dial reading was recorded once a stable value was displayed. The viscosity was directly read from the digital display in centipoise (cP) or calculated using the multiplication factor provided for the specific spindle and speed combination. Each sample was measured in triplicate, and the average viscosity value was calculated and recorded.

Irritancy Test

The irritancy test was performed to assess the potential of the cream formulations to cause skin irritation or sensitization when applied topically. The study was carried out using healthy human volunteers with prior informed consent. The test area, the volar forearm was cleaned with sterile water and dried. A small amount (about 0.5 g) of the cream formulation was applied to a marked area of 1–2 cm² and left uncovered. The test site was observed at regular intervals of 1 and 2 hours after application for any signs of erythema (redness), edema (swelling), itching, rash, or blistering. The severity of any skin reaction was graded using a standard scoring system such as the Draize scale, where

- 0 = No irritation
- 1 = Slight erythema or edema
- 2 = Moderate reaction
- 3 = Severe erythema or swelling

If no visible signs of irritation were observed within 2 hours, the formulation was considered non-irritant. If reactions were seen, the cream was classified accordingly based on the intensity and duration of the response. The test was repeated for each cream formulation in the study under identical conditions. Results were documented, and mean irritation scores were calculated for comparison among formulations.

In Vitro Permeation Studies

The in vitro permeation studies of cream were carried out with a Franz diffusion cell. 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 membrane (M.W 12000 – 14000 Da) was used as artificial membrane and was placed on receptor compartment. A quantity of Cream from each formulation batch was placed on the membrane (equivalent to 20 mg of curcumin) and both compartments were held tight by clamps. Phosphate buffer solution pH 6.8 with 2% tween 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 $37 \pm 1^\circ\text{C}$ with the help of hot plate. The study was carried out for 4 hours and at predetermined time interval 1 ml sample was withdrawn and the same volume of phosphate buffer pH 6.8 was added to receptor compartment to maintain sink conditions. The withdraw sample was analysed spectrophotometrically at 425 nm.

Drug Release Kinetics

The in vitro drug release data were tested with the following mathematical model. The best fitted model was found out to describe the kinetics of drug release.

Stability Studies

The purpose of stability study is to provide evidence on the quality of a drug substance or drug product which varies with time under the influence of a variety of environmental factors such as temperature, humidity and light. One formulation was selected for stability studies on the basis of physiochemical characteristics, in vitro drug release of the formulations. The formulation was subjected to accelerated stability studies as per ICH (The International Conference of Harmonization) guidelines. The most satisfactory formulation was sealed in an aluminium foil and stored at $40 \pm 2^\circ\text{C}$, $75 \pm 5\%$ RH for 6 months in stability chamber. Cream formulation was periodically removed and evaluated.

IV. RESULT AND DISCUSSION

UV-Spectroscopy (Determination of λ_{max})

The solution containing 10 ug/ml of Mahonia aquifolium extract in water was prepared and scanned over 200 -800 nm against blank solution using Shimadzu UV spectrophotometer. The maximum wave length was observed at 260 nm, which match with reported wave length.

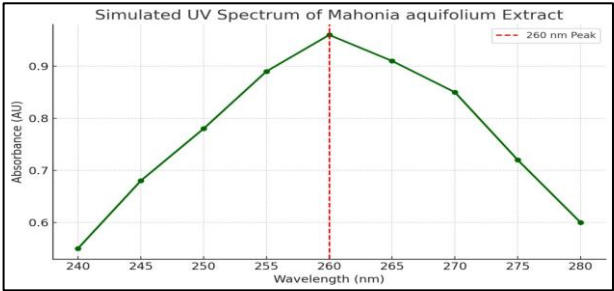


Figure 1: UV Absorption Spectra of Mahonia Aquifolium Extract

V. EVALUATION OF CREAM

Homogeneity

The homogeneity study was performed on all four cream formulations (F1 to F4) to assess their physical consistency, appearance, and texture. The observations are summarized below in table 2. All formulations exhibited satisfactory physical appearance and homogeneity, indicating proper dispersion of both active ingredients and base components. The absence of phase separation, clumping, or uneven texture suggests that the emulsification and mixing processes were appropriately conducted during formulation. Among the tested batches, F3 demonstrated the best overall smoothness and uniformity, likely due to the presence of silicone-based emollients (e.g., dimethicone and capric triglyceride), which enhance cream spreadability and textural feel. F1 showed slightly less refined texture compared to others, potentially due to the higher content of natural waxes (yellow beeswax and lanolin), which can affect cream softness. The consistency in appearance across batches confirms stable emulsions with no visible instability, indicating that the selected cream bases are compatible with the herbal extracts. These results support the suitability of the formulations for topical application in the management of psoriasis. The results are given in table 2.

Table 2: Homogeneity Study of Cream Formulation (F1 to F4)

Batch Code	Physical Appearance	Homogeneity	pH	Spread ability	Viscosity (cps)
F1	Pale yellow and grassy	Uniform, no clumps	5.6 ± 0.3	6.8 ± 0.2	$58,000 \pm 500$
F2	Off white and creamy	Smooth, uniform	5.8 ± 0.1	7.2 ± 0.3	$52,000 \pm 450$
F3	Light cream and smooth	Very smooth, uniform	5.5 ± 0.2	8.6 ± 0.1	$46,500 \pm 400$
F4	White and smooth cream	Smooth and homogeneous	5.6 ± 0.1	7.9 ± 0.2	$48,000 \pm 420$

pH

The pH values of the prepared cream formulations F1 to F4 were measured using a digital pH meter at room temperature ($25 \pm 2^\circ\text{C}$). The results are presented in the table 7.2. The pH values of all four Cream formulations were found to be within the acceptable range of 5.0 to 6.0, which is considered suitable for topical application on human skin. This range closely matches the natural pH of the skin, helping to minimize the risk of irritation or disruption of the skin's acid mantle. Batch F2 exhibited the highest pH (5.8), which may offer slightly better comfort in individuals with sensitive skin. Batch F3 had the lowest pH (5.5), still well within the safe dermatological range, suggesting compatibility for prolonged use. Batch F1 and F4 had identical pH values (5.6), indicating consistent buffering and formulation conditions.

Spreadability

The spreadability of Cream formulations is a critical parameter that influences the ease of application and user experience. The spreadability of all four cream formulations was determined using the parallel plate method, and the results are shown below table 4. Spreadability is an essential characteristic of a topical formulation as it affects patient compliance and ease of application. A cream that spreads easily is more desirable for uniform application and comfort, especially for chronic conditions like psoriasis where frequent and gentle application is necessary.

F4 showed good spreadability ($7.9 \pm 0.2 \text{ g}\cdot\text{cm}/\text{sec}$), likely due to its glycerin-rich and cetostearyl alcohol-based formulation, which provides a light, creamy texture. F2, which contains lanolin and mineral oil, had moderate spreadability ($7.2 \pm 0.3 \text{ g}\cdot\text{cm}/\text{sec}$), providing a balance between occlusiveness and ease of use.

Viscosity

Batch F1 exhibited the highest viscosity ($58,000 \pm 500 \text{ cP}$), attributed to its high content of white soft paraffin, yellow beeswax, and lanolin, which are all known to significantly increase the thickness of the base. This makes F1 a more occlusive and protective formulation, potentially suitable for extremely dry or cracked psoriatic skin, but it may be slightly more difficult to spread and extrude from tubes. Batch F2 showed a slightly lower viscosity ($52,000 \pm 450 \text{ cP}$) due to the substitution of waxy components with mineral oil

and propylene glycol, resulting in a less dense formulation that remains stable yet easier to apply. The viscosity results indicate that batch F3 and F4, due to their relatively lower viscosity, are more spreadable and cosmetically elegant, making them suitable for frequent application over large body areas in conditions like psoriasis. In contrast, F1, with the highest viscosity, offers better conclusiveness and may be preferable for localized lesions or overnight therapy.

Extrudability

Extrudability is a critical parameter in Cream formulations, reflecting the ease with which the Cream can be expelled from its container, directly influencing user experience and application efficiency.

Batch F3 demonstrated the highest extrudability ($510 \pm 12 \text{ g}/\text{cm}^2$), suggesting a semi-solid consistency that allows the cream to flow easily when slight pressure is applied. This enhanced extrudability can be attributed to the formulation's composition, which includes dimethicone, capric triglyceride, and glycerine ingredients known to lower viscosity and improve flow properties.

Batch F4 also showed good extrudability ($495 \pm 11 \text{ g}/\text{cm}^2$), likely due to the presence of glycerin and cetostearyl alcohol, which give the cream a smooth, creamy consistency that is easy to dispense.

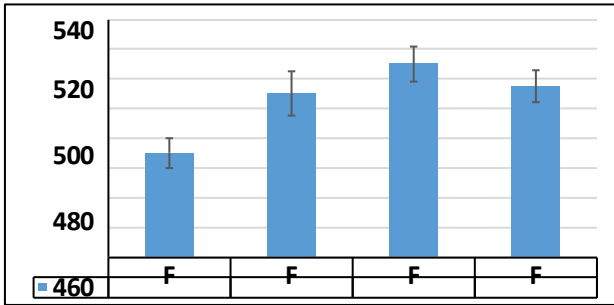


Figure 2: Extrudability Study of Cream Formulation (F1 to F4)

In Vitro Permeation Studies

The in-vitro permeation study of Mahonia aquifolium from cream formulations F1 to F4 was conducted using a Franz diffusion cell over a 6-hour period. The cumulative amount of drug permeated per unit area ($\mu\text{g}/\text{cm}^2$) was recorded at hourly intervals.

Table 3: In-Vitro Drug Permeation Study of Mahonia Aquifolium from Cream Formulation (F1 to F4)

Time (h)	F1	F2	F3	F4
0	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1	8.2 ± 0.5	10.1 ± 0.6	12.8 ± 0.6	11.5 ± 0.5
2	14.3 ± 0.8	17.6 ± 0.9	22.5 ± 1.1	20.1 ± 0.9
3	19.5 ± 1.1	24.3 ± 1.2	30.6 ± 1.3	27.5 ± 1.1
4	24.2 ± 1.2	30.5 ± 1.4	38.9 ± 1.5	34.3 ± 1.3
5	28.3 ± 1.4	36.1 ± 1.6	46.1 ± 1.7	40.6 ± 1.4
6	32.1 ± 1.5	41.4 ± 1.8	52.7 ± 1.8	46.5 ± 1.6

All values are mean $\pm$ SD (n=3)

Formulation F3 demonstrated the highest cumulative drug permeation at 6 hours ($52.7 \pm 1.8 \mu\text{g}/\text{cm}^2$), indicating a superior ability to release and transport the active component through the membrane. This enhanced permeation can be attributed to the inclusion of dimethicone and isopropyl myristate, and capric triglyceride, all known for their skin penetration-enhancing properties and ability to reduce the interfacial barrier between the cream and the skin.

Batch F4 also exhibited relatively high permeation ($46.5 \pm 1.6 \mu\text{g}/\text{cm}^2$), likely due to the presence of a glycerin-rich base, which promotes skin hydration and facilitates drug diffusion by loosening the stratum corneum.

Batch F2, which includes lanolin and mineral oil, showed moderate drug release ($41.4 \pm 1.8 \mu\text{g}/\text{cm}^2$). These ingredients provide occlusive properties but may slow diffusion by forming a semi-barrier, thus delaying drug penetration.

Batch F1 displayed the lowest drug permeation ($32.1 \pm 1.5 \mu\text{g}/\text{cm}^2$), which is consistent with its thick, occlusive base containing white soft paraffin, beeswax, and lanolin. These components tend to form a highly viscous matrix that retards drug release and permeation. The sustained and higher permeation observed in F3 and F4 suggests that these formulations are more suitable for topical treatment of psoriasis, as they allow for better skin delivery of Mahonia aquifolium, enhancing its anti-inflammatory and therapeutic effects.

Drug Release Kinetics

To understand the underlying mechanism of drug release from the developed cream formulations (F1–F4) of Mahonia aquifolium, in vitro drug permeation data were fitted to various mathematical models: Zero-order, First-order, Higuchi, and Korsmeyer-Peppas models. The correlation coefficient (R^2) values and diffusion exponent (n) obtained from the regression analysis are presented in Table 4.

Table 4: Drug Release Kinetics Study of Formulation (F1 to F4)

Formulation	Zero Order (R^2)	First Order (R^2)	Higuchi (R^2)	Peppas (R^2)	Peppas (n)
F1	0.9823	0.9941	0.9580	0.9993	0.7434
F2	0.9881	0.9988	0.9481	0.9999	0.7798
F3	0.9884	0.9994	0.9471	0.9998	0.7832
F4	0.9867	0.9991	0.9512	0.9998	0.7690

The drug release kinetics analysis revealed that all four formulations exhibited high R^2 values for the Korsmeyer-Peppas model ($R^2 > 0.999$), suggesting that the release mechanism is best described by a combination of diffusion and polymer relaxation (erosion) processes, commonly referred to as anomalous (non-Fickian) transport. The Peppas diffusion exponent (n) values ranged from 0.7434 to 0.7832, which lie between $0.5 < n < 1.0$, further confirming non-Fickian diffusion behavior.

Stability Studies

The optimized formulation F3 was chosen for the stability study. ICH recommendations were followed in conducting the expedited stability investigations. The Cream formulation was placed in aluminum tube and kept for three months in a stability chamber with a temperature of 40°C and a relative

humidity of 75% (Zone III conditions according to ICH Q1 criteria). The Cream formulation's appearance, spreadability, pH, viscosity and in vitro permeation were assessed both before and after the predetermined amount of time. The sample was watched for any changes in appearance after three months.

The stability study confirms that cream formulation F3 remains physically, chemically, and functionally stable after storage at 40°C . All key parameters pH, spreadability, viscosity, extrudability, and permeation—showed only negligible changes. These results indicate that F3 is a robust formulation with good shelf stability, making it suitable for long-term use in the treatment of psoriasis. The stability study data are shown in table 4.

Table 4: Stability Studies of Cream Formulations F3 Stored At (40°C)

Evaluation Parameter	Before Stability	After Stability
pH	5.5 ± 0.2	5.5 ± 0.1
Homogeneity	Very smooth, uniform	Very smooth, uniform
Spreadability (mm)	8.6 ± 0.1	8.2 ± 0.3
Viscosity (cps)	$46,500 \pm 400$	$46,400 \pm 250$
In Vitro Permeation Study (%)	52.7 ± 1.8	51.8 ± 1.5
Extrudability (g/cm2)	510 ± 12	506 ± 14

VI. CONCLUSION

The current study was aimed at the development and evaluation of a topical polyherbal

cream formulation containing Mahonia aquifolium, Indigo naturalis, and Aloe vera for the potential treatment of psoriasis, a chronic inflammatory skin disease. A systematic approach was employed to

formulate four different cream bases (F1 to F4) using various emollients, humectants, and penetration enhancers to assess their impact on physicochemical properties, skin compatibility, drug release behaviour, and stability. The identity and purity of Mahonia aquifolium extract were confirmed using UV- visible spectrophotometry. The extract showed a maximum absorbance (λ_{max}) at 260 nm, which aligns with literature-reported values. This confirmed the suitability of the method for quantitative analysis and supported the use of this wavelength in further analytical studies related to drug release and permeation. The optimized formulation, F3, underwent accelerated stability testing at 40°C for 3 months under ICH guidelines. The formulation was monitored for changes in pH, viscosity, spreadability, permeation, extrudability, and homogeneity. There were no significant changes in pH (remained at 5.5), homogeneity, or appearance. A slight reduction was observed in spreadability (from 8.6 to 8.2 g·cm/s) and viscosity (46,500 to 46,400 cP), likely due to minor moisture loss, but the product remained stable and user-friendly. Drug release efficiency was maintained with negligible decline (52.7% to 51.8%), indicating no compromise in performance after storage. Extrudability remained consistent, indicating maintained usability. These findings suggest that F3 has excellent shelf stability, maintains efficacy under accelerated conditions, and is suitable for long-term topical use.

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