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Effect of Hydroxypropyl Methylcellulose Concentration Variations as a Gelling Agent on the Physical Quality of Hydrogel Formulations Containing Ethanol Extract of *Impatiens balsamina L.* Herb

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ABSTRACT

Background: *Impatiens balsamina L.* herb is known to possess anti-inflammatory and antioxidant activities, making it a promising candidate for development as an active ingredient in topical formulations. Hydrogels are considered an ideal delivery system for topical wound treatment due to their ability to provide controlled drug release, with hydroxypropyl methylcellulose (HPMC) commonly employed as a stable gelling agent. This study aimed to evaluate the effect of varying HPMC concentrations on the physical quality of hydrogel formulations containing ethanol extract of *Impatiens balsamina L.* herb.

Subjects and Method: This was an experimental study. Hydrogel formulations were prepared with varying concentrations of hydroxypropyl methylcellulose (HPMC) at 1%, 2%, and 3% as the gelling agent. Each formulation was evaluated for physical quality parameters, including organoleptic properties, homogeneity, spreadability, adhesiveness, and pH value, following standard topical formulation testing procedures.

Results: The evaluation results showed that all formulations exhibited good homogeneity and pH values within the safe range for skin application. Increasing HPMC concentration did not visually affect the color of the formulations; however, it influenced the formulation consistency, decreased spreadability, and increased adhesiveness.

Conclusion: Variations in HPMC concentration in hydrogel formulations containing ethanol extract of Impatiens balsamina L. herb significantly affected the physical quality parameters, particularly consistency, spreadability, and adhesiveness. The formulation with 2% HPMC concentration demonstrated the most optimal physical characteristics for topical application.

Keywords: *impatiens balsamina L.* herb, hydrogel, hydroxypropyl methylcellulose

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BACKGROUND

Impatiens balsamina L, commonly known as garden balsam, is a plant belonging to the Balsaminaceae family and is widely cultivated in Indonesia. Traditionally, this plant has been utilized for medicinal purposes. In several countries, such as Malaysia, the leaves of *Impatiens balsamina* are used in traditional medicine to treat cracked nails (Ong et al., 2011). In several regions of India, the leaves of this plant are traditionally used to treat various types of inflammation, including skin inflammation (Ayasov et al., 2021). Such traditional applications have prompted numerous scientific investigations aimed at evaluating its pharmacological potential.

Several preclinical studies have demonstrated the pharmacological activeities of various parts of *Impatiens balsamina L*, showing promising anti-oxidant, antibacterial, and anti-inflammatory properties in in vitro experiments (Buana *et al.*, 2024). These activities are known to support the wound healing mechanism: the antioxidant activity helps neutralize free radicals, the antibacterial effect prevents wound infections, and the anti-inflammatory property facilitates the repair and regeneration of damaged tissues (Fauzian *et al.*, 2024). The combination of these three activities makes *Impatiens balsamina L* a promising candidate for the development of topical wound-healing formulations. To maximize its pharmacological potential, it is essential to design an appropriate dosage form that ensures optimal delivery and therapeutic effectiveness.

The selection of an appropriate dosage form for the delivery of active compounds significantly influences their therapeutic effectiveness. Topical formulations are considered the ideal choice for the localized delivery of bioactive compounds from *Impatiens balsamina* extract, particularly in wound management. Compared to other dosage forms, topical preparations offer direct effects, minimize systemic side effects, and are easy to apply. Moreover, effective topical formulations are expected to reduce the risk of wound infection (Ulviani et al., 2016). Among the various types of topical preparations, hydrogels are one of the most suitable for application on open wounds due to their ability to maintain moisture, thereby creating a cooling effect that helps reduce swelling in the injured area (Harliatika & Noval, 2021).

Hydrogels are a dosage form that offers several advantages in accelerating the wound healing process. They possess highly desirable characteristics for use as wound dressings, as they can help remove necrotic tissue, thereby facilitating the formation of new tissue and promoting faster wound recovery (Harliatika & Noval, 2021). Hydrogels maintain a moist wound environment by delivering water molecules directly to the wound area, and this moist condition provides several benefits that can accelerate and improve the quality of healing. Such an environment facilitates autolytic debridement, reduces pain, minimizes scar formation, stimulates collagen synthesis, and promotes keratinocyte migration across the wound surface.

Moreover, a moist environment supports the presence and function of nutrients, growth factors, and other soluble mediators within the wound microenvironment, all of which play crucial roles in the tissue repair process (Nuutila and Eriksson, 2021). The combination of these physical character-istics makes hydrogels an ideal wound dressing formulation that effectively supports optimal healing.

The physical characteristics of hydrogel formulations are highly influenced by formulation factors. One of the most critical factors determining the success of a

hydrogel formulation is the selection of an appropriate gelling agent. Hydroxypropyl methylcellulose (HPMC) is one of the most commonly used gelling agents in hydrogel formulations because it can form a stable, homogeneous, and water-soluble gel. In addition, HPMC is non-irritating and exhibits good in vitro permeability (Ciolacu et al., 2020). These properties make HPMC an ideal gelling agent for topical applications in wound care.

HPMC can produce a clear and transparent gel that remains stable within a pH range of 3 to 11 and maintains its viscosity during long-term storage (Rowe et al., 2009). Hydrogels formulated with HPMC as a gelling agent are known to provide the most suitable characteristics for the topical delivery of piroxicam as an anti-inflammatory agent (Abd-Allah et al., 2010) The use of HPMC as a delivery system is also known to form a coating layer around the active pharmaceutical ingredient, thereby controlling its release (Ciolacu *et al.*, 2020).

A study conducted by Abd-Allah et al. (2010) demonstrated that the release of piroxicam from a hydrogel formulation reached 94% within just 3 hours of the experiment. This rapid release is attributed to the physical quality characteristics, such as viscosity and rheological properties, of the hydrogel formulation prepared using HPMC as the gelling agent.

A hydrogel formulation with an excessively high concentration of HPMC may limit the spreadability and user comfort of the preparation. Conversely, formulations with a moderate concentration tend to maintain an optimal balance between viscosity and elasticity while preserving stability during storage. Therefore, this study aimed to investigate the effect of varying concentrations of HPMC as a gelling agent on the physical properties of hydrogel formulations containing the ethanol extract of Impatiens balsamina herb. The evaluation of the hydrogel's physical properties included organoleptic assessment, homogeneity test, spreadability test, adhesion test, and pH measurement.

SUBJECTS METHOD

1. Materials

The materials used in this study included ethanol extract of *Impatiens balsamina L.* herb, hydroxypropyl methylcellulose (HPMC), propylene glycol, methyl paraben, propyl paraben, and distilled water.

2. Instruments

The instruments utilized were an analytical balance (OHAUS Item PA 224, USA, Max capacity 220 g, readability 0.0001 g), glass beakers (Iwaki-Pyrex®), a water bath (Memmert), pH indicator paper (Macherey-Nagel 92110), and an oven (Memmert UNB 400).

3. Sample Collection and Preparation

Fresh *Impatiens balsamina L.* herb was collected from Mambal Village, Abiansemal Subdistrict, Badung Regency, Bali, and taxonomically identified. The plant material was washed, air-dried for approximately eight days at room temperature, then sliced into small pieces. Once completely dried, the samples were ground into a fine powder and sieved through a 20-mesh sieve.

4. Extraction of Plant Material

The ethanol extract of *Impatiens balsamina L.* herb was prepared by maceration using 70% ethanol as the solvent. The powdered plant material was soaked for 24 hours with occasional stirring and then filtered. The filtrate (macerate) was collected, and the residue was re-macerated once using the same method.

The combined macerates were concentrated using a rotary evaporator to remove ethanol and obtain a viscous extract (Sapara et al., 2016). The yield percentage

of the concentrated extract was then calculated.

5. Hydrogel Formulation

Hydrogel preparation began by weighing all required ingredients. The HPMC gel base was dispersed in hot distilled water in a mortar and allowed to swell. Methyl paraben and propyl paraben were dissolved in a small amount of hot distilled water (Mixture 1). The ethanol extract of *Impatiens balsamina L.* was dissolved in propylene glycol (Mixture 2). All mixtures were combined with the pre-swollen gel base and stirred until a homogeneous hydrogel mass was formed. Distilled water was added to adjust the final weight of the formulation to 100 g (Harliatika and Noval, 2021). Three different hydrogel formulations were prepared as shown in Table 1.

Table 1. Hydrogel Formulation of Ethanol Extract of *Impatiens balsamina L.* Herb

Ingredients	Function	Material Concentration (%)		
		F1	F2	F3
1. Ethanol extract of I. balsamina	Active ingredient	0.5	0.5	0.5
2. HPMC	*Gelling agent*	1	2	3
3. Propylene glycol	Humectant	15	15	15
4. Methyl paraben	Preservative	0.18	0.18	0.18
5. Propyl paraben	Preservative	0.02	0.02	0.02
6. Distilled water	Vehicle	Ad. 100 gram		

6. Evaluation of Hydrogel Formulations

The optimal hydrogel formulation was determined based on physical quality evaluation, including organoleptic characteristics, homogeneity, spreadability, adhesion, and pH.

a. Organoleptic Test

Organoleptic properties, including color, odor, and appearance, were observed and recorded (Sapara et al., 2016).

b. Homogeneity Test

Homogeneity was visually assessed by applying the hydrogel from three different points (top, middle, and bottom) onto a glass slide and covering it with a coverslip. The uniform distribution of components was observed microscopically (Sapara et al., 2016).

c. Spreadability Test

One gram of hydrogel was placed at the center of a glass plate marked with a millimeter block, covered with another glass plate, and subjected to a 125 g load for one minute. The spread diameter was measured in triplicate (Edy et al., 2016).

d. Adhesion Test

A 0.5 g sample of hydrogel was applied between two glass slides and subjected to a 1 kg load for five minutes. The slides were then mounted on an adhesion test device and subjected to an 80 g load. The time required for the slides to separate was recorded. The test was performed in triplicate (Kusuma et al., 2018).

e. pH Test

The pH was measured using universal pH indicator paper by dipping it into a diluted sample of the hydrogel (Kusuma et al., 2018).

7. Data Analysis

Data from organoleptic and homogeneity evaluations (color, odor, appearance, and uniformity) were analyzed descriptively. Physical stability data, including spreadability and adhesion, were analyzed using one-way ANOVA. A significance level of $p > 0.05$ was considered not significant, while $p < 0.05$ indicated a significant difference (Hariningsih, 2019).

RESULTS

Ethanolic Extract of Impatiens balsamina Herb

The *Impatiens balsamina* plants used in this study underwent a taxonomic determination process at the School of Life Sciences and Technology, Institut Teknologi Bandung, to ensure species authenticity and accuracy. The results confirmed that the sample was *Impatiens balsamina L.* After identification, the plant material was processed into simplicia following the standard procedure.

The ethanolic extract of *Impatiens balsamina* herb yielded 10.3% extract from a total of 1000 g of simplicia. In general, an extract yield above 7% is considered acceptable, depending on the type of plant and solvent used (Ministry of Health of the Republic of Indonesia, 2000). This yield indicates that the extraction method and solvent employed were effective in isolating bioactive compounds from the simplicia.

Evaluation of the Physical Properties of Ethanolic Extract Hydrogel

The physical properties of the ethanolic extract hydrogel, including organoleptic characteristics, homogeneity, spreadability, adhesiveness, pH, and consistency, were evaluated, and the results are summarized in Table 2.

Table 2. Physical Property Evaluation of Hydrogel Formulations Containing Ethanolic Extract of Impatiens balsamina

Formula	Color	Consistency	Odor	Homogeneity	Spreadability (cm)	Adhesiveness (s)	pH
F1	Brownish	Soft gel (+)	Characteristic odor of *Impatiens balsamina*	Homogeneous	6.43 ± 0.32*	0.79 ± 0.05*	6
F2	Brownish	Soft gel (++)	Characteristic odor of *Impatiens balsamina*	Homogeneous	5.07 ± 0.56*	2.07 ± 0.90*	6
F3	Brownish	Soft gel (+++)	Characteristic odor of *Impatiens balsamina*	Homogeneous	3.80 ± 0.10*	10.0 ± 0.20*	6

Note :
+ : Low softness
++ : Moderate softness
+++ : High softness
* : Statistically significant differences

Table 3. Statistical Analysis of Spreadability and Adhesiveness Tests

Comparison	Adhesiveness Significance	Spreadability Significance
F1 vs F2	$p < 0.01$	$p < 0.01$
F1 vs F3	$p < 0.01$	$p < 0.01$
F2 vs F1	$p < 0.01$	$p < 0.01$

Comparison	Adhesiveness Significance	Spreadability Significance
F2 vs F3	$p < 0.01$	$p < 0.01$
F3 vs F1	$p < 0.01$	$p < 0.01$
F3 vs F2	$p < 0.01$	$p < 0.01$

The macroscopic morphology of the ethanolic extract hydrogel formulations developed in this study is depicted in Figure 1, highlighting the variations in physical appearance and textural consistency across the three formulations.

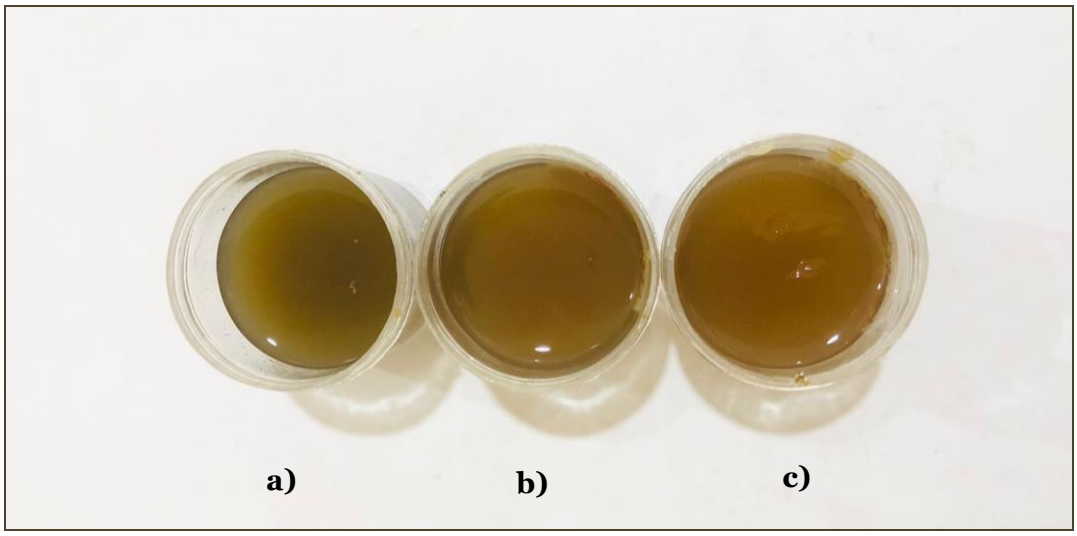

Figure 1. Physical appearance of ethanolic extract hydrogel formulations of Impatiens balsamina: (a) Formula I, (b) Formula II, (c) Formula III.

DISCUSSION

Organoleptic Evaluation

Organoleptic examination was conducted visually at room temperature by observing the color, form, and odor of the hydrogel preparations. The observations revealed that all three hydrogel formulations (F1, F2, and F3) exhibited a characteristic brownish color and a distinct odor derived from the ethanolic extract of Impatiens balsamina herb. There were no significant differences in color or odor among the formulations, despite the variations in HPMC concentration used as the gelling agent.

This indicates that HPMC, a neutral and colorless polymer, does not significantly influence these sensory characteristics (Noval et al., 2019). The consistency in color and odor also reflects the stability of the active compounds and the absence of degradation or chemical interactions between components that could alter visual or olfactory properties. The physical appearance of the hydrogel preparations for each formulation is shown in Figure 1.

However, differences were observed in terms of texture and physical consistency. The results demonstrated that increasing the concentration of HPMC had a significant impact on the viscosity of the hydrogel preparations. Formula 1 (1% HPMC) appeared more fluid and less viscous, whereas Formula 3 (3% HPMC) exhibited the highest viscosity and the softest texture. HPMC is a cellulose derivative capable of forming a gel network through hydrogen bonding with water molecules. At higher concentrations, poly-

mer chains interact to form a denser and more stable three-dimensional network, resulting in increased viscosity and changes in the physical characteristics of the preparation (Kibbe, 2000; Aulton & Taylor, 2018).

A more viscous consistency can enhance the preparation's ability to adhere to the skin surface and prolong retention time. However, it may also reduce the spreadability and patient comfort during application. Therefore, organoleptic parameters such as texture are not only important from a cosmetic perspective but are also directly related to the acceptability and clinical effectiveness of the hydrogel preparation.

Homogeneity Test

The homogeneity test was conducted to ensure that all components of the hydrogel, including the active substance and excipients, were evenly distributed. All three formulations demonstrated homogeneous distribution visually, indicated by the absence of clumps or coarse particles when applied to a glass slide. This result suggests that the mixing and formulation methods used were effective in producing stable and uniform gel preparations. According to Ulviani et al. (2016), good homogeneity reflects the physical stability of a preparation and influences the consistency of its therapeutic effects by ensuring uniform distribution of the active substance. Notably, increasing the concentration of HPMC did not compromise the homogeneity of the hydrogel, as even the highest concentration in F3 showed good component distribution. This indicates excellent compatibility between HPMC, the Impatiens balsamina extract, and other excipients.

Spreadability

Spreadability is a critical parameter in the evaluation of topical preparations as it reflects the ability of the preparation to spread across the skin surface. The spreadability of the three hydrogel formulations ranged from 3.80 ± 0.1 cm to 6.43 ± 0.32 cm. ANOVA analysis showed that these differences were statistically significant (Table 3). Formula 1 exhibited the highest spreadability, while Formula 3 showed the lowest.

Differences in spreadability are closely related to the viscosity of the preparation. As a hydrophilic polymer, HPMC forms a gel by interacting with water molecules, creating a dense three-dimensional network. Higher HPMC concentrations result in a denser and more viscous gel, increasing resistance to spreading forces and reducing the spread area (Rowe et al., 2009). According to Emelda et al. (2020), an ideal gel should have a spreadability range between 5 and 7 cm. Therefore, Formula 3, which falls below this range, may indicate suboptimal spreading ability on the skin.

These findings are consistent with the results of Noval et al. (2019), who reported an inverse relationship between HPMC concentration and spreadability, as increased viscosity inhibits gel movement. From a formulation standpoint, this parameter is crucial because low spreadability may make it difficult for patients to apply the gel over larger skin areas.

Adhesiveness

Adhesiveness refers to the hydrogel's ability to remain attached to the skin or membrane surface for a certain period. The test results demonstrated a significant increase in adhesiveness (Table 3) with increasing HPMC concentration, ranging from 0.79 ± 0.05 seconds (F1) to 10.0 ± 0.2 seconds (F3). Formula 1 exhibited adhesiveness below the ideal range of 2–300 seconds suggested by Batageri and Prabhu (2002), indicating that too low a concentration of HPMC produces a preparation that easily detaches from the skin surface.

The increase in adhesiveness occurs because HPMC possesses bioadhesive properties, enabling it to form hydrogen bonds with skin proteins. Higher polymer concentrations enhance these interactions, allowing the preparation to remain in place for a longer period (Pan et al., 2023). This increased adhesiveness has positive implications for topical therapy, as it allows more controlled release of the active substance and prolongs contact time with the skin, thereby improving therapeutic effectiveness.

However, excessive adhesiveness may cause discomfort for patients. Moreover, increased viscosity also affects the diffusion rate of the active compound through the skin layers. According to Binder et al. (2019), higher viscosity in a hydrogel preparation decreases the penetration rate of the active compound. Therefore, achieving a balance between spreadability and adhesiveness is essential for optimizing formulation performance.

pH Evaluation

The pH test was conducted to ensure that the resulting hydrogel preparation had an acidity level compatible with human skin physiology. All three formulations of the Impatiens balsamina ethanolic extract hydrogel showed a pH value of 6, which falls within the normal skin pH range of 4.5–6.5 (Thomas et al., 2023). A mismatch between the pH of the preparation and skin pH can disrupt the integrity of the stratum corneum, increase the risk of irritation, contact dermatitis, or imbalance of the skin microbiome (Loden & Maibach, 2000). Therefore, pH is an important quality parameter in topical product formulation, ensuring not only user comfort but also safety and therapeutic effectiveness, particularly for long-term use or on sensitive skin conditions.

The stable pH values across all three formulations also indicate that variations in HPMC concentration did not significantly affect the system's acidity. This is consistent with findings by Rashati and Suprayitno (2019), who reported that HPMC, as a non-ionic polymer, is neutral and does not substantially contribute to pH changes in gel preparations. Thus, HPMC is an ideal gelling agent for topical systems, as it is not only stable but also compatible with active compounds and the skin. Overall, the appropriate pH values indicate that all three hydrogel formulations are safe for use and hold significant potential as topical preparations without causing physiological skin disturbances.

AUTHORS CONTRIBUTION

Komang Dirga Mega Buana: Principal investigator; conceptualization of the study; formulation design; determination of physical quality parameters; execution of physical evaluation tests; and writing of the methodology and results sections.

Ni Luh Gede Wiwin Pebriani: Assisted in hydrogel formulation and physical evaluation; performed data analysis of physical quality parameters; and contributed to the discussion section.

Ade Irma Suryani: Responsible for documentation of the preparation process, statistical data processing, and contribution to the abstract and conclusion writing.

Ni Nyoman Yudianti Mendra: Provided input on the safety and pharmacological potential of *Impatiens balsamina* extract, reviewed potential clinical applications, and contributed to the background section.

I Dewa Agung Ayu Diva Candraningrat: Conducted literature review on pharmacological aspects of *Impatiens balsamina* and assessed its relevance to hydrogel utilization.

Maria Malida Vernandes Sasadara: Responsible for extraction processes, standardization of the crude drug and extract, and writing the materials and extraction methods sections.

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CONFLICT OF INTEREST

The authors declare that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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