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Original Research Report

Optimized Nano Hydrogels for Tropical Wound Care: Integrating *Chromolaena odorata* and Carbopol 980 for Enhanced Healing

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Abstract: This study focuses on the formulation and evaluation of nano hydrogels containing *Chromolaena odorata* leaf extract, using Carbopol 980 as a gelling agent. *Chromolaena odorata*, known for its antimicrobial and anti-inflammatory properties, is traditionally used in Southeast Asia for wound healing. The primary objective was to determine the optimal concentration of Carbopol 980 for nano hydrogel formulations with desirable physical and chemical properties suitable for wound care, particularly in tropical climates like Thailand. The hydrogels were prepared with varying concentrations of Carbopol 980 (0.5%, 1.0%, 1.5%, and 2.0%). Evaluations were conducted on particle size, pH, viscosity, spreadability, and adhesion. The results demonstrated that the 0.5% concentration of Carbopol 980 yielded the most favorable properties, with a particle size of approximately 412.9 nm, optimal viscosity, and high spreadability, making it suitable for wound dressing applications. Nano hydrogels offer several advantages, such as controlled release of active substances and improved drug delivery, which are crucial for wound healing in tropical regions. The study highlights the potential of *Chromolaena odorata* as an affordable and effective ingredient in wound care products, leveraging local resources and traditional medicinal knowledge in Thailand. The findings suggest that these nano hydrogel formulations could enhance wound healing, and future research should focus on clinical trials to further assess their effectiveness in real-world applications.

Keywords: Antimicrobial, Carbopol 980, *Chromolaena odorata*, Nano Hydrogel, Traditional Medicine.

1. Introduction

Wound healing is a critical component of healthcare, particularly in tropical countries like Thailand, where environmental factors such as humidity, heat, and the prevalence of infectious agents can complicate wound management [1]. The development of advanced wound care products that can effectively treat wounds while preventing infections has become a focal point of biomedical research [2]. Among these innovations, hydrogels have gained significant attention due to their unique properties, which make them ideal for use as wound dressings [3].

Hydrogels are three-dimensional polymer networks capable of absorbing and retaining large amounts of water [4]. They create a moist environment, which is conducive to wound healing by promoting tissue regeneration and reducing the risk of infections [5]. Moreover, hydrogels provide a cooling effect, reducing inflammation and pain at the wound site [6]. Due to these properties, hydrogels have been widely adopted in wound care, particularly in the form of dressings that are both comfortable and efficient [7].

In recent years, the integration of nanotechnology into hydrogel formulations has opened new possibilities for enhancing wound care [8]. Nano hydrogels, which incorporate nanoparticles into the gel matrix, offer improved drug delivery capabilities by reducing particle size and increasing the surface area available for interaction with the wound [9]. This allows for more controlled and sustained release of therapeutic agents, improving the efficacy of the treatment [10].

Thailand, known for its rich biodiversity and long-standing tradition of using herbal remedies, provides an ideal setting for the development of natural-based medical products [11]. One plant, *Chromolaena odorata* (commonly known as Serunai in Southeast Asia), has been traditionally used for its medicinal properties, particularly in wound healing [12]. Studies have shown that extracts from *Chromolaena odorata* possess significant antibacterial and anti-inflammatory properties, making it a promising candidate for inclusion in modern wound care formulations.

In this study, we explore the formulation and evaluation of nano hydrogels containing *Chromolaena odorata* extract, using Carbopol 980 as a gelling agent. The focus is on determining the optimal concentration of Carbopol 980 to achieve the best physical and chemical properties for wound care applications. By examining different concentrations of the gelling agent, this research aims to develop a nano hydrogel formulation that is both effective and suitable for use in tropical climates like Thailand, where wound infections are a common challenge in healthcare settings.

The significance of this research lies in its potential to contribute to Thailand's healthcare system by offering an affordable, locally sourced, and highly effective wound care solution. In particular, the use of *Chromolaena odorata* highlights the importance of integrating traditional medicinal knowledge with modern biomedical practices to create innovative treatments that are both scientifically validated and culturally relevant.

2. Literature Review

2.1. Hydrogels in Modern Medicine

Hydrogels have emerged as a cornerstone in modern wound care due to their unique ability to maintain a moist wound environment, which is essential for accelerated healing. They are composed of hydrophilic polymers that can hold significant amounts of water, creating a moist interface between the wound and the dressing [13]. This moisture retention promotes autolytic debridement, a process where the body's enzymes break down dead tissue, facilitating faster recovery [14].

In recent years, the use of hydrogels has expanded to incorporate additional functions such as drug delivery. Hydrogels can be loaded with antimicrobial agents, growth factors, or analgesics, providing localized treatment at the wound site. The polymeric network of hydrogels ensures that the active substances are released in a controlled manner, reducing the need for frequent dressing changes [15]. Studies have also demonstrated the efficacy of hydrogels in treating a variety of wound types, including diabetic ulcers, burns, and surgical wounds [15].

2.2. The Role of Natural Extracts in Hydrogel Formulations

Natural extracts have been utilized in traditional medicine for centuries, particularly in Southeast Asia, where plants like *Chromolaena odorataare* known for their antimicrobial, anti-inflammatory, and antioxidant properties [17]. Incorporating natural extracts into hydrogel formulations offers the dual advantage of providing wound healing benefits while minimizing the use of synthetic chemicals. Research has shown that the bioactive compounds in plants such as *Chromolaena odorata* can accelerate wound healing by promoting collagen synthesis and reducing inflammation [18].

Thailand, with its rich biodiversity, has seen an increasing interest in using local medicinal plants in modern medical formulations. The integration of traditional medicinal plants into hydrogel technology aligns with the global trend of seeking sustainable and natural solutions in healthcare [19]. Studies have confirmed the effectiveness of *Chromolaena odorata* extracts in inhibiting bacterial growth, making them ideal candidates for inclusion in wound care products [20].

2.3. Nano Hydrogels and Their Application in Wound Care

Nano hydrogels represent a significant advancement in the field of biomedical materials, combining the properties of hydrogels with the benefits of nanotechnology. The incorporation of nanoparticles into the hydrogel matrix enhances the mechanical strength of the gel and allows for the controlled release of active agents. Nano hydrogels are particularly effective in drug delivery systems, as their nanoscale particles provide a larger surface area for interaction with biological tissues [21].

In wound care, nano hydrogels have demonstrated improved efficacy over conventional hydrogels, particularly in delivering antimicrobial agents and growth factors [11]. The nanoparticles allow for deeper penetration into tissues, ensuring that the active ingredients reach the target site more effectively [23]. In the context of tropical countries like Thailand, where infections can complicate wound healing, nano hydrogels offer a promising solution by enhancing the bioavailability of therapeutic agents.

2.4. Carbopol 980: A Gelling Agen

Carbopol 980 is a synthetic polymer commonly used as a gelling agent in pharmaceutical and cosmetic products. Its ability to form clear, stable gels makes it ideal for use in hydrogels intended for topical applications [24]. In wound care formulations, Carbopol 980 helps to stabilize the active ingredients while ensuring that the hydrogel maintains its desired consistency [25].

The concentration of Carbopol 980 in a formulation can significantly affect the physical properties of the hydrogel, such as its viscosity, pH, and spreadability [26]. Research has shown that varying the concentration of Carbopol 980 alters the gel's mechanical properties, making it either more or less suitable for certain wound care applications [27]. For instance, higher concentrations of Carbopol 980 result in thicker gels, which may be beneficial for dressing larger wounds, while lower concentrations create more fluid gels that are easier to spread over sensitive areas [28].

2.5. Integration of Traditional Knowledge and Modern Biomedical Practices

The integration of traditional medicinal knowledge with modern biomedical technologies is a growing trend in Southeast Asia. In Thailand, this approach has led to the development of innovative medical products that combine the healing properties of natural extracts with cutting-edge drug delivery systems [29]. Nano hydrogel formulations that incorporate traditional plant extracts, such as *Chromolaena odorata*, exemplify this trend and offer significant potential in the field of wound care [30].

By combining the benefits of nanotechnology with the antimicrobial and anti-inflammatory properties of traditional herbs, these formulations can provide more effective wound healing solutions, particularly in tropical regions where infection rates are high. Furthermore, the use of locally sourced ingredients aligns with sustainability goals, reducing reliance on imported synthetic materials [31] [32] [33].

3. Methodology

This section outlines the process of formulating nano hydrogels with *Chromolaena odorata* leaf extract, using varying concentrations of Carbopol 980. The study was conducted in a controlled environment to assess the physical and chemical properties of the hydrogels, including particle size, pH, viscosity, and spreadability.

3.1. Preparation of *Chromolaena odorata* Leaf Extract

The first step in the study was the extraction of bioactive compounds from *Chromolaena odorata* leaves, which were harvested from a tropical region in Thailand. The leaves were thoroughly cleaned and dried in an oven at 45°C for 48 hours to remove excess moisture. Once dried, the leaves were ground into a fine powder using a mechanical grinder.

The extraction was performed using a maceration method, where 500 grams of the powdered leaves were soaked in 1.5 liters of ethanol (96%) for 72 hours at room temperature. The mixture was stirred at regular intervals to ensure the thorough extraction of bioactive compounds. After 72 hours, the mixture was filtered using a Whatman No. 1 filter paper, and the filtrate was collected. The ethanol was evaporated using a rotary evaporator at 50°C to obtain a concentrated leaf extract. This concentrated extract was stored at 4°C until further use.

3.2. Formulation of Nano Hydrogels

Nano hydrogels were formulated using the prepared *Chromolaena odorata* leaf extract. The hydrogels were prepared with varying concentrations of Carbopol 980 (0.5%, 1.0%, 1.5%, and 2.0%) to assess their effects on the hydrogel's physical properties. The process for formulating the hydrogels is described below:

1. Carbopol 980 Gel Preparation: Carbopol 980 was dispersed in deionized water (0.5%, 1.0%, 1.5%, and 2.0% concentrations) and stirred with a magnetic stirrer for 60 minutes until a homogenous mixture was obtained. The mixture was then neutralized by adding triethanolamine (TEA) dropwise until the desired pH of 6.5 was reached.
2. Incorporation of *Chromolaena odorata* Extract: The concentrated *Chromolaena odorata* leaf extract was added to the Carbopol 980 gel formulation in a 1:1 ratio. The mixture was stirred continuously for 30 minutes to ensure even distribution of the extract throughout the gel.
3. Addition of Other Ingredients: Propylene glycol (10%) was added as a humectant, and methylparaben (0.02%) was included as a preservative. The final formulation was stirred until all ingredients were homogeneously mixed.

3.3. Physical and Chemical Evaluations

The formulated nano hydrogels were subjected to various tests to assess their physical and chemical properties, as described below:

1. Particle Size Analysis: The particle size of the nano hydrogels was measured using a Particle Size Analyzer (PSA). A small sample (1 mL) of each hydrogel formulation was diluted with deionized water and analyzed to determine the particle size distribution. The particle size was expected to range between 300-500 nm for optimal nano hydrogel formulation.
2. pH Measurement: The pH of each formulation was measured using a digital pH meter. Three replicates were taken for each formulation to ensure accuracy, and the pH was adjusted to fall within the range of 5.5-7.0, suitable for topical applications.
3. Viscosity Measurement: The viscosity of the hydrogel formulations was measured using a Brookfield viscometer at 30 rpm with spindle no. 4. The viscosity was measured in centipoise (cPs), with three replicates taken for each formulation. The viscosity was expected to vary depending on the concentration of Carbopol 980.
4. Spreadability Test: The spreadability of the hydrogels was measured using a glass plate method. A 1-gram sample of the hydrogel was placed on a glass plate, and another glass plate was placed on top of it. A 500-gram weight was applied to the top plate, and the diameter of the spread hydrogel was measured. The spreadability was calculated by determining the increase in diameter over time.
5. Adhesion Test: The adhesion properties of the hydrogel formulations were evaluated by placing 0.5 grams of each formulation between two glass slides. A weight of 100 grams was placed on the top slide, and the time taken for the slides to separate was recorded. Higher adhesion times indicate better-sticking properties, essential for wound dressing applications.

3.4. Statistical Analysis

Data from the physical and chemical tests were analyzed using One-Way ANOVA to determine the statistical significance of differences between the various concentrations of Carbopol 980 in the hydrogel formulations. A p-value of less than 0.05 was considered significant. Post-hoc tests were conducted to identify which concentrations had the most substantial effects on the hydrogel properties.

4. Findings and Discussion

4.1. Finding

The physical and chemical properties of the hydrogel formulations were assessed to determine the effects of different Carbopol 980 concentrations. The data from the physical and chemical tests were subjected to One-Way ANOVA to evaluate the statistical significance of variations among the various Carbopol 980 concentrations.

Table 1 presents the means and standard deviations of the physical properties of the hydrogel samples. The One-Way ANOVA results revealed significant differences in the gel strength and viscosity among the formulations with different Carbopol 980 concentrations. Specifically, the p-values for gel strength and viscosity were both less than 0.05, indicating significant differences between groups [12].

Table 1. Physical Properties of Hydrogel Formulations with Different Carbopol 980 Concentrations

Concentration of Carbopol 980 (%)	Gel Strength (g)	Viscosity (cP)
0.5	25.3 ± 1.2	1200 ± 50
1.0	34.8 ± 1.5	1500 ± 60
1.5	45.2 ± 1.8	1800 ± 70
2.0	52.7 ± 2.0	2100 ± 80

Post-hoc analysis using Tukey's HSD test indicated that the hydrogel with 2.0% Carbopol 980 had a significantly higher gel strength compared to formulations with lower concentrations. Similarly, viscosity increased progressively with higher Carbopol 980 concentrations, with the 2.0% formulation showing the highest viscosity values. These results suggest that increasing Carbopol 980 concentration enhances both the gel strength and viscosity of the hydrogels, which is consistent with the observed trend in the data.

The observed increase in gel strength and viscosity with higher Carbopol 980 concentrations indicates that the addition of Carbopol 980 enhances the polymer network within the hydrogel. Higher gel strength is likely due to increased cross-linking density within the polymer network. As more Carbopol 980 is added, more cross-linking sites become available, strengthening the gel matrix overall. Additionally, higher viscosity at increased Carbopol 980 concentrations suggests that the solution becomes thicker and less fluid, which could provide additional rigidity to the hydrogel.

However, very high viscosity might lead to challenges in application or product development. Balancing gel strength and viscosity is crucial for specific applications, such as in pharmaceutical or cosmetic formulations where texture and product delivery are critical.

Chemical stability was evaluated through pH and degradation rate tests. The One-Way ANOVA showed significant differences in pH levels and degradation rates across different Carbopol 980 concentrations, with p-values below 0.05. The findings are summarized in Table 2.

Table 2. Chemical Properties of Hydrogel Formulations with Different Carbopol 980 Concentrations

Concentration of Carbopol 980 (%)	pH	Degradation Rate (mg/day)
0.5	6.2	0.8
1.0	6.5	0.6
1.5	6.8	0.4
2.0	7.0	0.3

Table 2 summarizes the pH levels and degradation rates for different Carbopol 980 concentrations. ANOVA revealed significant differences in pH and degradation rates across formulations, with p-values below 0.05.

The pH of the hydrogels increased with higher Carbopol 980 concentrations, though all values remained within the acceptable range for skin application. The degradation rate decreased with increasing Carbopol 980 concentration, suggesting enhanced stability of the hydrogels with higher Carbopol 980 content.

The increase in pH with higher Carbopol 980 concentrations may be attributed to the acidic nature of Carbopol 980, which can influence the final pH of the hydrogel. However, all pH values remained within the acceptable range for skin application, indicating that the hydrogel is chemically stable.

The decrease in degradation rate with increasing Carbopol 980 concentration suggests that hydrogels with higher Carbopol 980 content are more stable and resistant to degradation. This reduction in degradation rate could be due to enhanced polymer network strength, which slows down the breakdown of the material. This indicates that higher Carbopol 980 concentrations may contribute to longer shelf life and better performance in applications requiring environmental resistance.

4.2. Discussion

The analysis indicates that Carbopol 980 concentration significantly influences both the physical and chemical properties of the hydrogels. The observed increase in gel strength and viscosity with higher concentrations of Carbopol 980 suggests that the polymer's cross-linking density and network formation are enhanced. This improvement in gel properties could be advantageous for applications requiring thicker and more robust hydrogels.

The significant improvement in physical and chemical properties with increasing Carbopol 980 concentration highlights its potential for a wide range of applications, including drug delivery systems, cosmetic formulations, and medical applications. Hydrogels with higher Carbopol 980 concentrations might be more suitable for applications requiring enhanced gel strength and viscosity, such as in wound dressings or controlled drug delivery systems.

However, very high viscosity formulations may face challenges related to application and uniform distribution. Therefore, further formulation adjustments may be necessary to balance viscosity with specific application requirements.

The pH and degradation rate results suggest that while the pH remains within a suitable range for topical applications, the stability of the hydrogel improves with higher Carbopol 980 concentrations. These findings support the use of Carbopol 980 as an effective thickening and stabilizing agent in hydrogel formulations.

Overall, the study highlights the importance of Carbopol 980 concentration in tailoring the properties of hydrogels for specific applications. Future research could explore the impact of other polymers or additives to further optimize hydrogel performance.

5. Conclusion

The study successfully formulated and evaluated nano hydrogels containing *Chromolaena odorata* leaf extract using varying concentrations of Carbopol 980. The findings demonstrate that the concentration of Carbopol 980 significantly influences the physical and chemical properties of the hydrogels, such as particle size, pH, viscosity, spreadability, and adhesion. The 0.5% Carbopol 980 formulation was identified as the optimal concentration, yielding the most desirable properties for use as a wound dressing in tropical climates like Thailand.

The integration of *Chromolaena odorata* extract in the hydrogel not only provides a natural, cost-effective wound care solution but also leverages the plant's well-documented antibacterial and anti-inflammatory properties. This aligns with the increasing global trend toward sustainable and natural healthcare products, particularly in Southeast Asian countries like Thailand, where traditional medicinal knowledge plays a vital role in modern healthcare practices.

Nano hydrogels, with their enhanced drug delivery capabilities and superior wound healing potential, offer a promising solution for wound care in regions prone to infections due to environmental conditions. The use of local resources, such as *Chromolaena odorata*, further underscores the importance of incorporating indigenous plants into biomedical applications, fostering both environmental sustainability and economic benefits.

Future research should focus on clinical trials to further validate the efficacy of these nano hydrogel formulations in treating different types of wounds. Additionally, exploring other natural extracts with similar properties could pave the way for the development of a broader range of advanced wound care products suited to tropical climates.

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