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Gel Formulation from Pineapple Leaf Waste with Propylene Glycol Variations for Burn Wound Healing

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ABSTRACT

Despite their potential medicinal properties, pineapple leaves (*Ananas comosus L. Merr*) are an underutilized agricultural waste. These leaves contain flavonoids, which are known for their ability to aid in wound healing, particularly for burns as a gel. Propylene glycol plays an important role in the formulation of gels due to its ability to enhance the penetration and absorption of active compounds, such as flavonoids from the pineapple leaves. It also helps in maintaining the gel's consistency, ensuring it remains stable and effective for topical applications. in this study, varying concentrations of propylene glycol (0%, 10%, 20%, 30%, and 40%) were tested for their efficacy in burn wound healing in Rats. Gel production was prepared by the extraction of pineapple leaf waste and mixed with propylene glycol in varying concentrations (10-40%) and gel additives. The gel was then applied to burn wound healing in rats. The study involved five groups: four treatment groups receiving gel with propylene glycol concentrations of 10%, 20%, 30%, and 40%, and a control group without using gel. Results indicated that the pineapple leaf gel significantly accelerated burn wound healing compared to the control group. Among the formulations, gels with 20% and 30% propylene glycol concentrations demonstrated the most effective and rapid healing properties. These findings highlight the potential of pineapple leaf extract as an economical and sustainable option for topical burn treatment, encouraging further exploration and optimization of its formulation for clinical applications.

Keywords: Gel formulation, Pineapple Leaf Waste, propylene glycol, would healing

1. INTRODUCTION

Pineapple (*Ananas comosus L. Merr*) is a tropical fruit widely cultivated for its nutritional and economic value. However, its by-products, particularly pineapple leaves, are often discarded as agricultural waste despite their potential for repurposing. Pineapple leaves contain flavonoids, bioactive compounds recognized for their antioxidant, anti-inflammatory, and wound-healing properties. These characteristics make pineapple leaves a promising natural resource for developing therapeutic products, particularly for burn treatment [1], [2].

Burn injuries are common and can lead to complications such as infections, prolonged recovery, and scarring if not treated effectively. Current treatments often rely on synthetic ointments and gels, which may be costly and sometimes produce undesirable side effects. The growing interest in natural remedies has highlighted plant-based extracts as affordable, biocompatible, and sustainable alternatives. Pineapple leaf extract, when formulated into a gel, offers an innovative approach to utilizing agricultural waste while addressing a critical healthcare need[3], [4].

Propylene glycol is a key component in topical formulations and plays an essential role in enhancing the effectiveness of wound-healing gels. As a humectant, it helps maintain moisture at the wound site, preventing dehydration and promoting cell regeneration. Its solubilizing properties enable active compounds, such as flavonoids, to penetrate deeper layers of the skin, enhancing their therapeutic effects. Additionally, propylene glycol contributes to the gel's consistency and spread ability, ensuring even application over the wound area. Optimizing its concentration is crucial, as it directly influences the gel's efficacy and patient comfort[5], [6].

This study aims to formulate a gel from pineapple leaf extract with varying concentrations of propylene glycol (10%, 20%, 30%, and 40%) and evaluate their efficacy in promoting burn wound healing. White rats (*Rattus norvegicus*) were selected as experimental models due to their physiological similarity to humans in wound-healing processes, making them a reliable choice for preclinical studies. The objective of this research are to assess the wound-healing potential of pineapple leaf extract and to determine the optimal concentration of propylene glycol that maximizes its effectiveness. By combining natural bioactive compounds with carefully designed formulations, this study seeks to develop an affordable, eco-friendly, and effective treatment for burn injuries, while encouraging the utilization of underused agricultural resources.

2. MATERIALS AND METHODS

2.1 Materials.

The materials comprised both raw and chemical components. The raw material used was pineapple leaves sourced from Purbalingga, Indonesia, meeting the criteria of dark and light green colors. The chemical ingredients included Nipagen Methyl Paraben, Propylene Glycol, Carbopol/Carbomer 940, Ethanol 70%, Glycerin, Distilled Water, and TEA (Triethanolamine).

2. 2 Research Procedure

2.2.1 Preparation of Pineapple Leaf Extract

50 g pineapple leaves were washed under running water and cut into small pieces, then sun-dried until they turned white-brown. The dried leaves were blended into a fine powder and sieved using a tea strainer. The resulting powder (84.5 g) was measured using an analytical balance and mixed with 845 ml of 70% ethanol in a beaker glass. The mixture was stirred manually for 1 hour and covered with aluminum foil to prevent evaporation. The maceration process was left undisturbed for 24 hours in a dark environment. The macerated solution (filtrate) was filtered using a flannel cloth to separate the liquid from the residue. The filtrate was then placed in a bowl set above a saucepan with water for evaporation on a low blue flame. The resulting concentrated extract was measured using a graduated cylinder, yielding 18 ml of pineapple leaf extract.

2.2.2 Preparation of Gel Formulation

The gel was prepared using a mortar, which was cleaned and dried to prevent contamination. Distilled water (250 ml) was heated on a stove for 2 minutes. All ingredients were measured using a 10 ml measuring cup and an analytical balance.

Each component was added to the mortar in the required amounts (**Table 1**) and mixed until homogenized. The formulations contained 1 ml of pineapple leaf extract and varying concentrations of propylene glycol (10%, 20%, 30%, and 40%). The resulting gels were labeled as samples A, B, C, and D. The analysis organoleptic of gel in consistency, color, and appearance was conducted by researchers.

2.2 Treatment and Observation of gels into burn wound healing in rats

White rats (*Rattus norvegicus*) were prepared by shaving their fur using a razor. A burn wound was induced by heating a nail for 30 seconds and pressing it against the skin for 1 second, creating a first-degree burn characterized by pink redness and slight swelling[7].

The rats were divided into five groups:

1. Sample A: Treated with a gel containing 10% propylene glycol.
2. Sample B: Treated with a gel containing 20% propylene glycol.
3. Sample C: Treated with a gel containing 30% propylene glycol.
4. Sample D: Treated with a gel containing 40% propylene glycol.
5. Sample E: No treatment (control group).

Treatment was administered twice daily (morning and evening) from day 1 to day 4. The wounds were left open during the healing process, with recovery marked by closure and merging of the wound edges. Data collected in this study were analyzed to evaluate the effectiveness of the gel formulations with varying propylene glycol concentrations in accelerating burn wound healing. The primary parameters observed included the rate of wound closure, reduction in redness and swelling, and the overall healing time. The wound area was measured using a transparent graph sheet placed over the wound. The size of the wound was calculated daily by tracing its outline on the sheet and counting the grid units covered by the wound. This process was repeated for all samples (A, B, C, D, and E) from day 1 to day 4 to monitor the progression of wound healing[7], [8].

Table 1. Formulation of the sample using 10 – 40 % of Propylene glycol

Ingredients	PG 10%	PG 20%	PG 30%	PG 40%
Pineapple leaf extract	1 ml	1 ml	1 ml	1 ml
Propylene Glycol	0,7 ml	2 ml	2,7 ml	4 ml
Gliserin	1 ml	1 ml	1 ml	1 ml
Carbopol	1 gr	1 gr	1 gr	1 gr
Nipagin	1 gr	1 gr	1 gr	1 gr
Aquadest	1 ml	1 ml	1 ml	1 ml
TEA	1 ml	1 ml	1 ml	1 ml

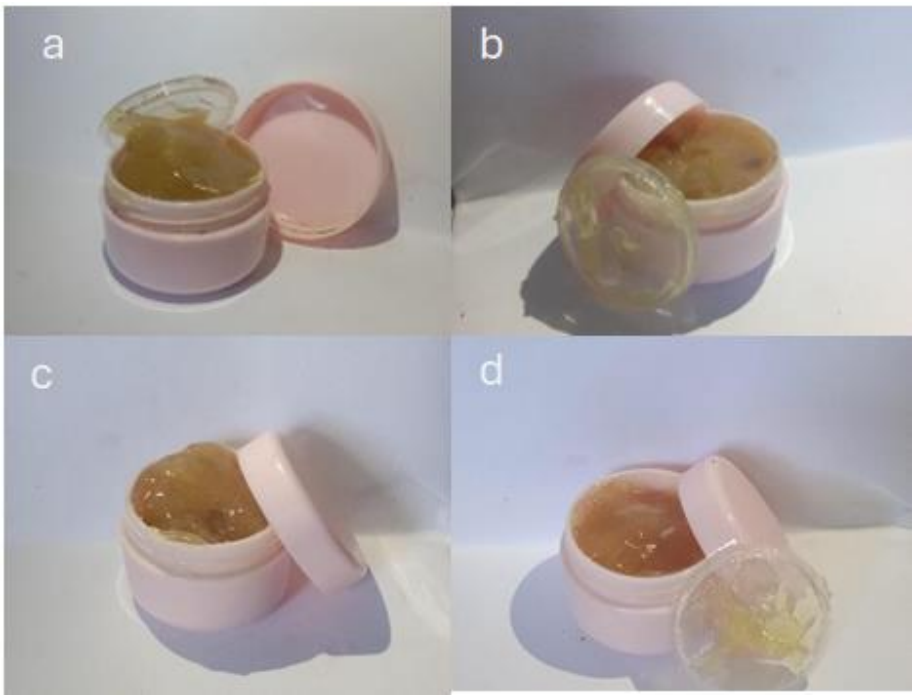

Figure 1. The pineapple leaf extract gels using the different concentrations of propylene glycol (a) 10%, (b) 20%, (c) 30%, (d) 40%.

Table 1. The organoleptic test for the pineapple leaf extract gels in different concentrations of Propylene glycol (PG).

Formulation	Color	Smell	Homogeneity
PG 10%	Canary Yellow	Characteristic of Extract	Homogeneous
PG 20%	Pastel Yellow	Characteristic of Extract	Homogeneous
PG 30%	Canary Yellow	Characteristic of Extract	Homogeneous
PG 40%	Canary Yellow	Characteristic of Extract	Homogeneous

3. RESULTS AND DISCUSSION

3.1 Physical appearance of gels formulated from pineapple leaf extract with different concentrations of propylene glycol

The formulated pineapple leaf gel was subjected to organoleptic and homogeneity tests. The appearance of the gels is shown in **Figure 1**. The organoleptic test visually observed the gel's texture, color, and smell. The homogeneity test aimed to assess the uniformity of the ingredients in the gel formulation, ensuring that the gel mixture was well-mixed. **Table 2** summarizes the results of the organoleptic and homogeneity tests for the four pineapple leaf gel formulations.The results of this study indicate that the concentration of propylene glycol in the pineapple leaf gel formulation significantly influenced the rate of burn wound healing in white rats. The formulation with 10% propylene glycol demonstrated slower healing compared to the higher concentrations. While the pineapple leaf extract still provided some healing benefits, the lower concentration of propylene glycol may have limited its effectiveness in facilitating the absorption of the extract's bioactive compounds. Propylene glycol is known for its ability to enhance skin penetration, and at 10%, it might not have been sufficient to optimize the absorption of the flavonoids and other active ingredients from the pineapple leaf extract. As a result, the healing rate was moderate, and wound closure was slower when compared to higher propylene glycol concentrations.

The 20% propylene glycol concentration showed promising results in wound healing. The formulation at this concentration struck a balance between maintaining adequate moisture in the wound area and enhancing the absorption of active compounds from the pineapple leaf extract. Propylene glycol, at 20%, likely provided an optimal moisture environment that facilitated epithelial cell migration and collagen formation, both essential for wound repair. The healing was noticeably faster compared to the 10% formulation, with quicker reduction in redness and swelling, and a more pronounced reduction in the wound area. This suggests that 20% propylene glycol may be an ideal concentration for burn wound healing in this formulation.

The 30% propylene glycol concentration exhibited the most significant wound-healing effects among all the formulations tested. This concentration seemed to provide an ideal environment for accelerated healing. At 30%, propylene glycol likely enhanced the delivery of the active compounds from the pineapple leaf extract more efficiently than at lower concentrations. Moreover, the higher concentration helped to retain moisture in the wound, preventing scab formation and promoting a faster recovery process. The gel with 30% propylene glycol showed the fastest wound closure, with a noticeable reduction in swelling and redness. This formulation seems to offer an optimal combination of hydration and penetration, maximizing the healing potential of the extract.

While the 40% propylene glycol concentration also facilitated wound healing, its performance was slightly less effective than the 20% and 30% formulations. Excessive amounts of propylene glycol can lead to overhydration of the wound area, which might hinder the natural scabbing and scarring process. At this higher concentration, the gel could have created a too-moist environment that slowed the final stages of healing, despite promoting earlier wound recovery. This overhydration may have caused the skin cells to regenerate more slowly, leading to a slightly prolonged healing time compared to the 20% and 30% formulations.

The control group, which received no treatment, showed the slowest healing process, with persistent redness, swelling, and larger wound areas throughout the study period. This confirms that the pineapple leaf extract, even in the presence of low concentrations of propylene glycol, contributed to faster healing than no treatment at all. The absence of treatment in this group further highlights the potential benefits of using natural extracts, particularly those with anti-inflammatory and antioxidant properties, for burn wound healing.

The presence of flavonoids in pineapple leaf extract played a significant role in promoting wound healing. Flavonoids are known to exhibit antioxidant and anti-inflammatory properties, which aid in reducing oxidative stress and inflammation at the wound site. These properties likely accelerated cell proliferation and tissue regeneration, contributing to the closure of burn wounds in the treated groups. Propylene glycol is a critical component in topical formulations, functioning as a humectant and penetration enhancer. It maintains an optimal moisture balance in the wound area, creating a favorable environment for epithelialization and healing. Additionally, it improves the solubility and skin absorption of the active compounds in the pineapple leaf extract.

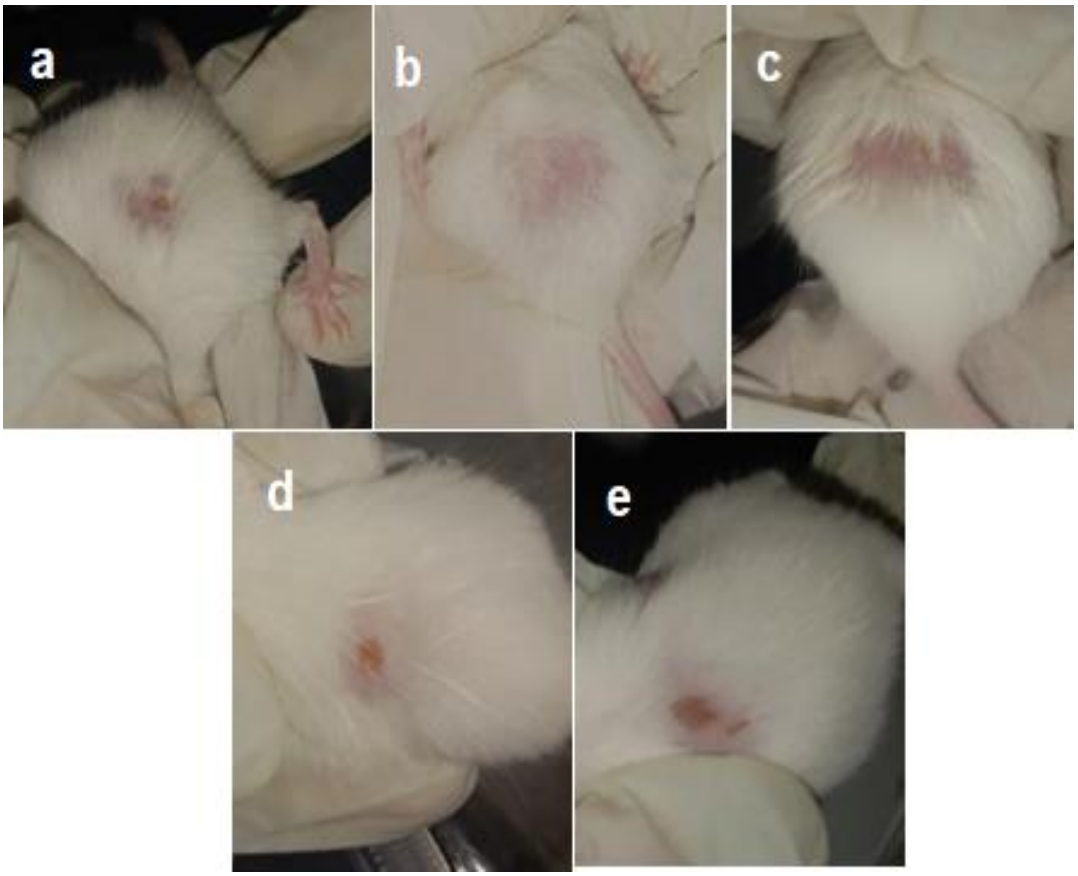

Figure 2. The burn wound healing using pineapple leaf extract gels using the different concentrations of propylene glycol (a) Sample A, (b) Sample B (c) Sample C (d) Sample C (e) Sample E (negative control)

The results showed that gels with propylene glycol concentrations of 20% (Sample B) and 30% (Sample C) exhibited the most significant wound-healing effects. These concentrations balanced the gel's moisture-retention capacity and the penetration efficiency of active compounds. The formulation with 40% propylene glycol (Sample D), while effective, showed slightly reduced performance, potentially due to excessive humectant properties, which could lead to overhydration and delayed healing. Conversely, the 10% concentration (Sample A) was less effective, likely due to insufficient enhancement of active compound penetration[7], [9].

3.2 The Effectiveness of Pineapple Leaf Extract in Wound Healing in rats

It was tested on white rats (*Rattus norvegicus*) to evaluate the healing time for each treatment. A total of five rats were used in this experiment. The results of burn wound healing after 4 days in rats are presented in **Figure 2**. The rats were induced with first-degree burn wounds using a heated nail, and the respective gel treatments were applied twice daily (morning and evening) from day 1 to day 4. The healing process was monitored, and the wound area was measured to determine the effectiveness of each formulation in promoting healing. The results showed that the gel formulations with 20% and 30% propylene glycol concentrations (Samples B and C) had the fastest healing rates, significantly reducing wound size compared to the control group. Sample E, which did not receive treatment, exhibited the slowest healing with visible redness and swelling throughout the study period. The data suggest that propylene glycol concentrations of 20% and 30% enhance the wound healing process, likely due to the optimized balance of moisture retention and active compound delivery provided by these concentrations.

The concentration of propylene glycol plays a crucial role in optimizing the effectiveness of pineapple leaf gel for burn wound healing. While all concentrations containing pineapple leaf extract exhibited healing properties, the formulations with

20% and 30% propylene glycol were the most effective, with 30% propylene glycol showing the fastest healing times. These concentrations likely provided the ideal balance between moisture retention and active compound delivery, which are essential for accelerated wound repair. Conversely, lower (10%) and higher (40%) concentrations were less effective, highlighting the importance of achieving the right formulation for optimal healing. These findings suggest that future formulations for burn wound treatment should focus on these concentrations to maximize therapeutic benefits[9], [10].

4. CONCLUSION

In conclusion, the gel formulation from pineapple leaf waste with varying concentrations of propylene glycol has shown promising potential as an effective treatment for burn wound healing. The study demonstrated that the pineapple leaf extract, enriched with bioactive compounds like flavonoids, plays a crucial role in promoting wound repair through its antioxidant and anti-inflammatory properties. The addition of propylene glycol, especially at concentrations of 20% and 30%, enhanced the absorption of these compounds while maintaining an optimal moisture balance in the wound area, thus accelerating the healing process. The formulations with 30% propylene glycol were the most effective, providing the fastest wound closure and reducing redness and swelling more significantly compared to the control group and other concentrations. These findings suggest that pineapple leaf waste, combined with the appropriate concentration of propylene glycol, could be a cost-effective and natural alternative for burn wound care, with further potential for wider therapeutic applications in the future.

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CONFLICT OF INTEREST

No potential conflict of interest was reported by the author(s).

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Vinda Afrilia Adi: Conceptualization, Methodology, Investigation, Data curation, Data analysis, Writing original draft.
Gitanjali Darmawan: Data curation, Data analysis, Methodology
Rian Dewi Saputri Azahra: Data curation, Data analysis
All authors have read and agreed to the published version of the manuscript.

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