AXION Health Multidisciplinary Journal (AHMJ)

Formulation Optimization of a Combined Mangosteen and Red Dragon Fruit Peel Extract Gel with Varying Carbopol 940 Concentrations

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Keywords:

Dragon fruit
Mangosteen
Carbopol 940
Gel
Optimization

ABSTRACT

One potential approach to enhance the benefits of mangosteen peel (*Garcinia mangostana* L.) and red dragon fruit peel (*Hylocereus polyrhizus*) is by formulating them into a gel dosage form. Carbopol 940 is a commonly used gelling agent, and its concentration must be carefully optimized as it significantly affects the gel's physical characteristics and the absorption of active compounds through the skin. This study aimed to optimize and evaluate the physical properties of a gel formulation containing a combination of ethanolic extracts of mangosteen peel and red dragon fruit peel using varying concentrations of Carbopol 940 as the gelling agent. The experimental design employed three Carbopol 940 concentrations, 1%, 1.5%, and 2%, and the prepared gels were evaluated for organoleptic characteristics, homogeneity, adhesion, spreadability, pH, and viscosity. The results showed that increasing the concentration of Carbopol 940 led to higher viscosity and adhesion but reduced spreadability, resulting in a thicker gel consistency. Overall, the most optimal formulation was Formula 2, containing 1.5% Carbopol 940, as it met the required physical properties for a stable and well-balanced gel preparation.

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INTRODUCTION

Mangosteen peel (*Garcinia mangostana* L.) and red dragon fruit peel (*Hylocereus polyrhizus*) contain beneficial bioactive compounds such as flavonoids, alkaloids, saponins, and tannins, which exhibit antibacterial, anti-inflammatory, and antioxidant properties. One promising approach to maximize the therapeutic potential of these natural materials is by developing them into a gel formulation. Gel preparations contain a high amount of water and provide more effective drug delivery compared to other topical formulations (Juliana et al., 2024). They offer several advantages, including easy spreadability upon skin application, a cooling sensation, rapid absorption, non-greasiness, and user comfort (Affandy et al., 2021).

An optimal gel formulation can be achieved by selecting and combining suitable components, particularly the gelling agent, which plays a crucial role in determining the gel's physical characteristics and stability (Emelda et al., 2020). A good gelling agent should ensure stability,

be easy to apply, provide comfort without stickiness, and be safe for the skin without causing irritation (Thomas et al., 2023). Among various gelling agents, Carbopol 940 is one of the most commonly used due to its excellent compatibility with active compounds, pleasant user acceptability, clear organoleptic appearance, and ability to form a viscous gel at relatively low concentrations (Putri et al., 2021). The typical concentration range for Carbopol 940 is between 0.5% and 2%, where higher concentrations yield thicker gels (Thomas et al., 2023). However, Carbopol 940 cannot form a stable gel in acidic conditions; thus, an alkalizing agent such as triethanolamine (TEA) is required to adjust the pH. While TEA influences the viscosity of the formulation, it cannot independently form a gel without the presence of Carbopol 940 (Rahmatullah, 2020).

The concentration of the gelling agent must be carefully optimized, as it significantly affects the gel's physical properties and the skin absorption of active compounds. Therefore, evaluating the physical characteristics of the gel is essential to determine the optimal concentration of Carbopol 940 for the combined ethanolic extract gel of mangosteen peel (*Garcinia mangostana* L.) and red dragon fruit peel (*Hylocereus polyrhizus*).

METHODS

Instruments and Materials

The instruments used in this study included an analytical balance, mortar and pestle, spatula, glass slides, pH meter, ruler, stopwatch, glass jars, stirring rods, water bath, aluminum foil, flannel cloth, measuring cylinders, beakers, separatory funnel, test tubes, Bunsen burner, dropper pipettes, watch glasses, spatulas, hot plate, porcelain dishes, Brookfield viscometer, and gel containers. The materials used consisted of powdered simplicia of red dragon fruit peel and mangosteen peel, 2N HCl, $FeCl_3$, Mayer's reagent, magnesium, Carbopol 940, propylene glycol, methyl paraben, triethanolamine (TEA), distilled water, and 70% ethanol.

Research Design

This study was an experimental laboratory research aimed at determining the most suitable gel formulation containing ethanolic extracts of mangosteen peel (*Garcinia mangostana* L.) and red dragon fruit peel (*Hylocereus polyrhizus*) based on physical evaluation parameters, with variations in the concentration of Carbopol 940 as the gelling agent. The research was conducted from February to March 2025 at the Pharmaceutical Technology Laboratory and the Clinical & Social Pharmacy Laboratory, Faculty of Health Sciences, Alma Ata University, Yogyakarta, as well as the Biology Laboratory, Faculty of Science and Applied Technology, Ahmad Dahlan University, Yogyakarta. Data analysis was performed using SPSS version 22, including normality testing (Shapiro–Wilk), homogeneity testing (Homogeneity of Variance), One-Way ANOVA, and post hoc tests based on the physical evaluation data, which included organoleptic, homogeneity, pH, spreadability, adhesion, and viscosity tests.

Sample Collection

The mangosteen peel powder (*Garcinia mangostana* L.) used in this study was obtained from Lansida Group, Purbayan, Kotagede, Yogyakarta, which provided materials with a Certificate

of Analysis (CoA). The red dragon fruit peel powder (*Hylocereus polyrhizus*) was purchased from Herbeat.id, located at Jl. Wijaya Kusuma No. 63, Condongcatur, Depok, Sleman, Yogyakarta. Since this material did not have a CoA, a simplicia identification test was conducted to confirm the authenticity of the plant material used in the study.

Identification of Red Dragon Fruit Peel Powder

The identification of red dragon fruit peel simplicia (*Hylocereus polyrhizus*) was carried out at the Biology Laboratory, Faculty of Science and Applied Technology, Ahmad Dahlan University, Yogyakarta. This procedure aimed to verify that the simplicia used in this study was correctly identified as red dragon fruit peel.

Preparation of Mangosteen and Red Dragon Fruit Peel Extracts

The extraction of mangosteen peel and red dragon fruit peel was performed using the maceration method. A total of 500 g of each powdered peel was macerated in 3.75 L of 70% ethanol at a ratio of 1:7.5 for 3 × 24 hours, with stirring every 24 hours for 5 minutes. The mixture was filtered using a flannel cloth to obtain the filtrate and residue. The residue was re-macerated for 2 × 24 hours using 1.25 L of the same solvent at a ratio of 1:2.5 (Rahmawati et al., 2023). The filtrates from the maceration and re-maceration processes were combined and evaporated using a water bath at 60°C (Riyo et al., 2019) until a thick extract was obtained. The yield percentage was then calculated (Yunita & Anwarudin, 2020).

Preparation of Gel Formulation

According to Table 1, the necessary instruments and materials were prepared. The mangosteen peel extract and red dragon fruit peel extract were each dissolved in 5 mL of propylene glycol. The gelling agent, Carbopol 940, was then dispersed in warm distilled water (80°C) according to the concentration in each formulation and stirred continuously in a mortar to facilitate hydration and gel formation. Triethanolamine (TEA) was added gradually and triturated until a uniform gel mass was obtained. Separately, methyl paraben was dissolved in 5 mL of distilled water heated to 75°C and then combined with the remaining propylene glycol, stirring until homogeneous. The previously dissolved extracts were added into the gel base and mixed thoroughly until a uniform dispersion was achieved. Finally, the remaining distilled water was added to make up to 100 mL, and the mixture was stirred until homogenous (Lestari, 2024). The prepared gels were then transferred into tightly closed containers for further evaluation.

Table 1. Formulation of Combined Gel Containing Mangosteen Peel Extract (Garcinia mangostana L.) and Red Dragon Fruit Peel Extract (Hylocereus polyrhizus) (Varges et al., 2019)

Ingredient	Function	Formula I (%)	Formula II (%)	Formula III (%)
Mangosteen peel extract	Active ingredient	2	2	2
Red dragon fruit peel extract	Active ingredient	2	2	2
Carbopol 940	Gelling agent	1	1.5	2
Propylene glycol	Humectant	15	15	15
Methyl paraben	Preservative	0.2	0.2	0.2
Triethanolamine (TEA)	Alkalizing agent	1.5	1.5	1.5
Distilled water	Solvent	ad 100	ad 100	ad 100

Notes: Formula I: 1% Carbopol 940, Formula II: 1.5% Carbopol 940, Formula III: 2% Carbopol 940

Evaluation of Gel Formulation

Organoleptic Test

The physical appearance of each gel formulation—including color, odor, and texture—was observed visually (Maria Ulfa et al., 2023).

Homogeneity Test

Homogeneity was assessed by spreading a small amount of the gel onto a glass slide to ensure that the formulation was evenly mixed and free from coarse particles or visible phase separation (Erliani et al., 2024).

pH Test

The pH of each formulation was measured using a calibrated pH meter. An acceptable pH range for topical gels is 4.5–6.5, ensuring safety for skin application without causing irritation or dryness (Hanifah et al., 2021).

Spreadability Test

Approximately 0.5 g of gel was placed on a glass plate, covered with another glass plate, and a 150 g weight was applied for one minute. The diameter of the spread gel was then measured with a ruler. This test evaluates the ease of application and spreading of the gel (Fatmawati et al., 2023).

Adhesion Test

A 0.5 g sample of the gel was placed between two glass slides and compressed with a 1 kg weight for five minutes. The time required for the two slides to separate was recorded after removing the weight. A good adhesive property is indicated when the adhesion time exceeds four seconds (Zaky et al., 2021).

Viscosity Test

The viscosity, which affects the ease of application, was measured using a Brookfield viscometer equipped with spindle No. 4 at a speed of 60 rpm for one minute. An ideal gel formulation should exhibit a viscosity between 2,000 and 50,000 cP (Ma'wah et al., 2024).

RESULTS AND DISCUSSION

Identification of Red Dragon Fruit Peel Powder

The identification process was conducted at the Biology Laboratory, Faculty of Science and Applied Technology, Universitas Ahmad Dahlan Yogyakarta. Based on the verification letter No. 492/Lab.Bio/B/IX/2024, the sample used in this study was confirmed to be red dragon fruit peel powder (*Hylocereus polyrhizus*), confirming its suitability for research purposes (Figure 1).

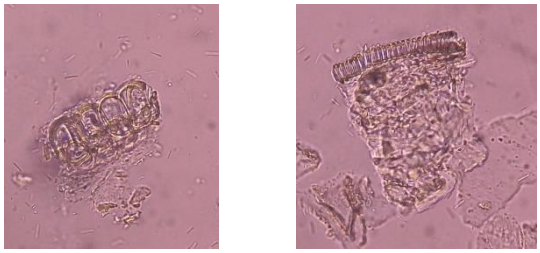

Figure 1. Microscopic analysis

Extraction of Mangosteen and Red Dragon Fruit Peels

The extraction of mangosteen peel (*Garcinia mangostana* L.) and red dragon fruit peel (*Hylocereus polyrhizus*) powders was performed using the maceration method. This method was chosen because it is simple, does not require heating, and thus prevents degradation or loss of thermolabile active compounds (Widyasanti et al., 2021). Each 500 g of powdered sample was macerated in 3.75 L of 70% ethanol (1:7.5 ratio of sample to solvent) for 3 × 24 hours, with stirring for 5 minutes every 24 hours (Fatah et al., 2024). The residue was then re-macerated using 1.25 L of the same solvent (1:2.5 ratio) for 2 × 24 hours. The combined filtrates from maceration and re-maceration were evaporated using a water bath at 60°C until a viscous extract was obtained (Riyo et al., 2019). The extraction yields are summarized in Table 2, showing that the mangosteen peel extract had a yield of 12.4% with a yellowish-brown color, while the red dragon fruit peel extract had a yield of 15.8% with a reddish-brown color. Both values met the minimum extract yield requirement of ≥10% (Rosa et al., 2023).

Table 2. Extraction Yield of Mangosteen Peel (*Garcinia mangostana* L.) and Red Dragon Fruit Peel (*Hylocereus polyrhizus*)

Sample	Weight of Simplicia (g)	Extract Weight (g)	Yield (%)	Color
Mangosteen peel	500	62	12.4	Yellowish brown
Red dragon fruit peel	500	79	15.8	Reddish brown

Phytochemical Screening

Phytochemical screening was carried out at the Clinical and Social Pharmacy Laboratory, Faculty of Pharmacy, Universitas Alma Ata Yogyakarta. This test aimed to identify the secondary metabolites present in the extracts through color or precipitate formation reactions. The screening was conducted for four major phytochemical groups: flavonoids, alkaloids, saponins, and tannins. The results, presented in Table 3, indicate that both mangosteen and red dragon fruit peel extracts contain all four compound classes, as evidenced by positive color reactions.

Table 3. Phytochemical Screening Results of Mangosteen Peel and Red Dragon Fruit Peel Extracts

Compound Group	Reagent	Observation	Result
Flavonoid	Aquadest + Mg + 2N HCl	Reddish orange color	+
Alkaloid	2N HCl + Aquadest + Mayer's reagent	Yellowish-white precipitate	+
Saponin	Aquadest + 2N HCl	Foam formation	+
Tannin	10% $FeCl_3$	Greenish-black color	+

(+): Present (–): Absent

Evaluation of Physical Properties

The concentration of Carbopol 940 as the gelling agent significantly affects the physical properties of the gel, including organoleptic characteristics, homogeneity, adhesion, spreadability, pH, and viscosity. The evaluation was performed to determine the optimal concentration of Carbopol 940 in the combined gel of mangosteen and red dragon fruit peel extracts.

a. Organoleptic Test

As shown in Table 4, the organoleptic evaluation assessed the gel's color, odor, and form without using instruments. Formulations I and II produced semi-solid gels, while formulation III (2% Carbopol 940) appeared slightly thicker. All formulations had the characteristic odor of the natural extracts. The color of the gel became lighter yellow with increasing Carbopol 940 concentration, due to denser gel network formation that reduced trapped air particles, resulting in a clearer appearance.

Table 4. Organoleptic Evaluation of Gel Formulations

Formula	Form	Color	Odor
F1 (1% Carbopol 940)	Semi-solid	Brown	Characteristic extract odor
F2 (1.5% Carbopol 940)	Semi-solid	Brown	Characteristic extract odor
F3 (2% Carbopol 940)	Semi-solid	Brown	Characteristic extract odor

b. Homogeneity Test

The homogeneity test (Table 5) showed that all three formulations (F1–F3) were visually uniform, with no coarse particles or uneven gel clumps observed, confirming that all gels met homogeneity standards.

Table 5. Homogeneity Results of Gel Formulations

Formula	Rep 1	Rep 2	Rep 3
F1	Homogeneous	Homogeneous	Homogeneous
F2	Homogeneous	Homogeneous	Homogeneous
F3	Homogeneous	Homogeneous	Homogeneous

c. Statistical Evaluation of Physical Properties

The statistical analysis of gel properties is summarized in Table 6. Variations in Carbopol 940 concentration significantly affected pH, viscosity, adhesion, and spreadability ($p < 0.05$). As the concentration of Carbopol 940 increased, viscosity and adhesion also increased, while pH and spreadability decreased.

Table 6. Statistical Evaluation of Physical Properties of Gel Formulations

Evaluation	F1 (1%)	F2 (1.5%)	F3 (2%)	p-Value
pH	6.10 ± 0.10	4.73 ± 0.20	4.16 ± 0.20	0.000*
Viscosity (cP)	3255 ± 729.60	4325 ± 444.68	6814 ± 573.73	0.001*
Adhesion (s)	3.93 ± 0.66	9.68 ± 0.74	13.39 ± 0.68	0.000*
Spreadability (cm)	6.56 ± 0.20	5.60 ± 0.36	4.33 ± 0.15	0.000*

(*Significant difference by ANOVA at 95% confidence level)

An increase in Carbopol 940 concentration led to thicker gels with higher viscosity and adhesion, but reduced pH and spreadability. The 1.5% Carbopol 940 formulation (F2) achieved a balance between viscosity, spreadability, and adhesion, providing stable texture and ease of application without excessive stickiness. Conversely, the 2% Carbopol 940 gel was overly viscous, making application less convenient.

CONCLUSIONS

Based on the evaluation results, the most optimal gel formulation combining mangosteen peel extract (Garcinia mangostana L.) and red dragon fruit peel extract (Hylocereus polyrhizus) was Formula II, containing 1.5% Carbopol 940, as it met all physical property requirements for an ideal gel preparation.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the Pharmacy Department, Universitas Alma Ata, for providing the laboratory facilities and support essential for the completion of this research.

FUNDING STATEMENT

No external funding was received for this study.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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