

The Effect of Xanthan Gum, HPMC, and Carbomer Polymer Variations on the Physical Properties and Stability of Fresh Mahkota Dewa Leaf 96% Ethanol Extract Gel Preparations

Rakhmi Hidayati*, Zunalia Firmansyah, Sukarno, Sri Fitrianiingsih

Institut Teknologi Kesehatan Cendekia Utama Kudus, Indonesia

*Corresponding Author: rahmicendekia@gmail.com

Abstract. Gel is a topical dosage form widely used for its comfort during application, ease of use, and non-sticky texture. Daun mahkota dewa (*Phaleria macrocarpa*) leaves contain flavonoids and tannins that act as antioxidants, giving them potential as an active ingredient in gel formulations, in which the type of gel-forming polymer plays an important role in determining stability and physical characteristics. This study aimed to determine the effect of xanthan gum, HPMC, and carbomer on the physical properties and stability of a gel containing 96% ethanol extract of fresh mahkota dewa leaves. This was an experimental study using three gel formulations, each containing one polymer xanthan gum (F3), HPMC (F1), and carbomer (F2) at 1.5%, together with 1.5% of the extract. Evaluations included organoleptic properties, homogeneity, pH, viscosity, spreadability, adhesion, and physical stability using centrifugation at 3000 rpm for 30 minutes, analyzed with SPSS using Shapiro-Wilk, Levene's, ANOVA, Kruskal-Wallis, Tukey, or Mann-Whitney tests as appropriate. All formulas showed a semi-solid form, dark green color, homogeneity, and characteristic aroma. The HPMC gel had the highest pH (7.95), greatest spreadability (5.06 cm), viscosity of 1,773.7 mPa·s, and adhesion of 1.32 seconds; the carbomer gel had the lowest pH (6.68), highest viscosity (9,725.8 mPa·s), lowest spreadability (3.03 cm), and highest adhesion (2.24 seconds); the xanthan gum gel showed pH 7.65, viscosity of 1,452.6 mPa·s, spreadability of 4.56 cm, and the lowest adhesion (0.81 seconds). All formulas were physically stable, with no phase separation after centrifugation. Xanthan gum, HPMC, and carbomer therefore have different effects on the physical properties and stability of the gel; carbomer produced the most viscous gel with the highest adhesion, HPMC gave the most neutral pH and best spreadability, while xanthan gum showed the lowest viscosity and adhesion but remained physically stable.

Keywords: Gel; *Phaleria macrocarpa*; Xanthan Gum; HPMC; Carbomer

INTRODUCTION

The skin is the largest organ covering the entire outer surface of the human body. It consists of three layers the epidermis, dermis, and hypodermis—each with distinct anatomical functions (Yousef *et al.*, 2024). The epidermis, the outermost layer, serves as the first line of defense against external damage such as pollutants and sunlight, prevents infection, and regulates body temperature (Prakoeswa & Sari, 2022). The epidermis is composed of keratinized stratified squamous epithelium and consists of five layers: the stratum basale (cuboidal or columnar cells), stratum spinosum (polyhedral cells with intercellular bridges), stratum granulosum (3–5 layers of flattened cells containing keratohyalin granules), stratum lucidum (found only in thick skin), and the outermost stratum corneum, comprising 15–20 layers of keratinized flattened cells (Inggriyani & Hidayaturrahmi, 2022).

The hypodermis, also known as the subcutaneous fascia, lies beneath the dermis and contains fat lobules, sensory neurons, blood vessels, and skin appendages such as hair follicles (Yousef *et al.*, 2024). Continuous exposure to ultraviolet (UV) radiation triggers free-radical formation in the skin, damaging cell membranes; the resulting oxidative stress contributes to uneven pigmentation, structural skin damage, and premature wrinkles and sagging (Harmileni *et al.*, 2024).

Antioxidants suppress or prevent free-radical and oxidant activity, protecting tissue from damage (Handajani, 2019). Although the body has natural antioxidant enzymes, these are often insufficient to neutralize excess free radicals (Kurniawati & Sutoyo, 2021), so facial skin requires additional antioxidants from external sources (Sulistiyowati, 2023).

Flavonoids are a well-established group of phenolic compounds with antioxidant properties. Mahkota dewa is a native Indonesian plant known for its antioxidant activity; spectroscopic analysis has revealed flavonoids particularly of the flavone type acting as antioxidants (Herlina *et al.*, 2022), making it a promising candidate for natural skin-care formulations. Herlina *et al.* (2022) reported that 96% ethanol extract of fresh mahkota dewa leaves has an IC₅₀ of 90.97 ppm (strong antioxidant activity), higher than that of dried leaves (IC₅₀ 108.5 ppm, moderate). Mahkota dewa fruit shows very strong

activity (IC₅₀ 28.242 ppm) (Putri *et al.*, 2020). Fresh leaf extract was chosen for this study due to the limited literature specifically evaluating its potential in gel formulations.

Anti-aging cosmetics with high antioxidant content help care for facial skin by preventing premature aging (Winarsi, 2007). Gel, one of the most common cosmetic dosage forms, spreads well on the skin, does not form an occlusive layer or clog pores, provides a cooling sensation, washes off easily, is comfortable on hairy skin areas, and releases active drugs well (Voigt, 1994; Sulistyowati, 2023). Gel is a semisolid system of small inorganic particles or large organic molecules dispersed in a liquid; when formed from discrete small particles it is a two-phase system, such as aluminum hydroxide gel, sometimes called a magma when the dispersed particles are relatively large, e.g., bentonite magma (Depkes RI, 2020). The key formulation component is the gelling agent (Ansel, 2005) a natural or synthetic gum, resin, or hydrocolloid that balances liquid and solid components, increases viscosity, and stabilizes the gel while remaining easy to apply, comfortable, non-sticky, and non-irritating (Thomas *et al.*, 2023).

Polymers used in gel preparations fall into three categories—natural, semi-synthetic, and synthetic (Agustiani *et al.*, 2022). Xanthan gum, a natural gelling agent, is stable in both acidic and alkaline conditions, remains effective at low concentrations, is pseudoplastic, and resists changes in temperature and pH (Aisyah *et al.*, 2022). HPMC, a semi-synthetic polymer, is valued for its stable pH and protective colloidal properties that prevent particle coalescence (Sulistyowati, 2023). Carbomer, a synthetic polymer, is hydrophilic, disperses easily in water, and produces sufficient viscosity even at low concentrations (Rowe *et al.*, 2009). Because these three polymers represent distinct categories with complementary characteristics, this study compares xanthan gum, HPMC, and carbomer to determine the most stable, effective gel formulation compatible with 96% ethanol extract of fresh mahkota dewa leaves.

METHODS

This study used a quantitative method with an experimental approach, systematically manipulating the independent variable (polymer type) and measuring its effect on the dependent variables (physical properties and stability) while controlling other variables, to obtain valid and reliable data.

Instruments and Materials. A Brookfield viscometer, measuring cylinders, test tubes, an analytical balance, a magnetic stirrer, pH paper and a pH meter, a watch glass, spatula, stirring rod, beaker glass, thermometer, adhesion- and spreadability-test apparatus, a stopwatch, and standard laboratory glassware were used. Materials included 96% ethanol extract of mahkota dewa leaves, HPMC, carbomer, xanthan gum, propylene glycol, TEA, and distilled water, plus magnesium metal, concentrated HCl, Mayer's, Dragendorff's, and Bouchardat's reagents, and 1% FeCl₃ for phytochemical screening.

Phytochemical Screening. The test solution was prepared by dissolving 500 mg of extract in 50 mL of 96% ethanol (Susanti *et al.*, 2014). Flavonoid test: the heated solution was treated with magnesium powder and HCl; a red color indicated flavonoids (Rubianti *et al.*, 2022). Saponin test: the solution was shaken with distilled water and then HCl; stable foam indicated saponins (Akasia *et al.*, 2021). Tannin test: three sub-samples were treated as a blank, with 10% FeCl₃ (blue/greenish-black = positive), and with gelatin salt (precipitate = positive) (Pauline, 1991; Marlina *et al.*, 2005).

Gel Formulation. Three formulas (F1 = HPMC, F2 = carbomer, F3 = xanthan gum) each contained 1.5% polymer, 1.5% extract, 20% glycerin, 12% propylene glycol, 2% TEA, and distilled water to 100 g (Table 1). For F1, HPMC was dispersed in hot water (≈80°C) to form a gel base, mixed with glycerin, propylene glycol, and diluted extract, adjusted to pH 5–7 with TEA, and homogenized at low speed for 10–15 minutes (Setiani & Endriyatno, 2023). For F2, carbomer was dispersed in water (≈70°C), mixed with the same additives, and pH-adjusted with TEA (Sugihartini *et al.*, 2018). For F3, xanthan gum was swollen in hot water (≈70°C), ground to a stable gel mass, then combined with the same additives and pH-adjusted with TEA (Aisyah *et al.*, 2022).

Table 1. Gel Formulation of 96% Ethanol Extract of Fresh Mahkota Dewa Leaves (%)

Ingredient	F1	F2	F3	Function
Xanthan Gum	–	–	1.5	Gel-forming base
Glycerin	20	20	20	Humectant
Propylene Glycol	12	12	12	Humectant
TEA	2	2	2	Alkalizing agent
Distilled Water	Ad 100	Ad 100	Ad 100	Main solvent

Physical Testing. Organoleptic properties (shape, color, aroma) were assessed visually (Maria *et al.*, 2018). Homogeneity was checked by spreading 0.1 g of gel on glass (Aisyah *et al.*, 2022). Spreadability was measured by applying 0.5 g of gel between glass plates with incremental 50 g weights (Kindangen *et al.*, 2018). Adhesion was measured as the time for two object glasses to separate under a 250 g load (Kindangen *et al.*, 2018). Viscosity was measured with a Brookfield viscometer (Aisyah *et al.*, 2022), and pH with a calibrated pH meter (Putri *et al.*, 2019). Physical stability was assessed by centrifugation at 3000 rpm for 30 minutes, equivalent to 10 months of storage (Sinko, 2007).

Statistical Analysis. Data were tested for normality (Shapiro-Wilk, $n < 50$) and homogeneity (Levene's test), each significant at $p > 0.05$. Normally distributed, homogeneous data were analyzed with one-way ANOVA and Post Hoc Tukey; normally distributed but non-homogeneous data used ANOVA with Games-Howell; non-normal or non-homogeneous data used Kruskal-Wallis with Mann-Whitney, all at $p < 0.05$.

RESULTS AND DISCUSSION

Material Identification and Phytochemical Screening. The 96% ethanol extract of fresh mahkota dewa leaves was obtained from the UPT Lansida Laboratory, Yogyakarta, via maceration, and TLC testing confirmed a positive reaction for flavonoids. Phytochemical screening (Table 2) showed positive results for flavonoids and tannins but negative for saponins.

Table 2. Phytochemical Screening Results

Screening	Reagent	Result	Description
Flavonoid	Mg and HCl	+	Green to yellowish-green
Saponin	2N HCl	–	Foam disappeared
Tannin	FeCl ₃	+	Blackish-green

The yellow color in the flavonoid test indicates formation of a flavylum salt, consistent with Larasati and Putri (2023) and Dewi *et al.* (2021), who explained that magnesium and HCl reduce the benzopyrone core of the flavonoid structure. The blackish-green tannin result matches Putri *et al.* (2023); according to Ergina *et al.* (2014), this reflects a complex between tannin and Fe³⁺ ions. The negative saponin result is consistent with Herlina *et al.* (2022); Putri & Lubis (2020) note that foam formation depends on the hydrophilic/hydrophobic balance in the saponin structure, so its absence indicates the compound is not present.

Organoleptic, Homogeneity, Spreadability, and Adhesion. All three formulas were dark green, semi-solid, with a characteristic aroma (Table 3) and were homogeneous across all replicates (Table 4), consistent with Sari *et al.* (2024) and Aisyah *et al.* (2022).

Table 3. Organoleptic and Homogeneity Test Results

Formula	Color	Odor	Shape	Homogeneity
F1	Dark Green	Characteristic	Semi-solid	Homogeneous
F2	Dark Green	Characteristic	Semi-solid	Homogeneous
F3	Dark Green	Characteristic	Semi-solid	Homogeneous

The spreadability and adhesion results are shown in Table 4. Based on SNI No. 06-2588 (5–7 cm ideal range), only F1 met the spreadability requirement (5.06 cm); F1's more liquid consistency—

consistent with Rakhma *et al.* (2020) gave it the best spreadability, while F2 (3.03 cm) and F3 (4.56 cm) did not meet the requirement. For adhesion, a good result exceeds 1 second (Zatz & Kushla, 1989): F1 (1.32 s) and F2 (2.24 s) met this criterion, consistent with Agustiani *et al.* (2022), while F3 (0.81 s) did not.

Table 4. Spreadability and Adhesion Test Results

Formula	Spreadability (cm)	Requirement	Adhesion (s)	Requirement
F1	5.06	5–7 cm	1.32	> 1 s
F2	3.03	5–7 cm	2.24	> 1 s
F3	4.56	5–7 cm	0.81	> 1 s

Viscosity and pH. All formulas met the ideal viscosity range of 500–10,000 mPa·s (St. Rahmatullah *et al.*, 2020): F1 = 1,773.7 mPa·s, F2 = 9,725.8 mPa·s, and F3 = 1,452.6 mPa·s, with carbomer producing the highest viscosity, consistent with Khafi *et al.* (2024) and Sawiji *et al.* (2024). All pH values (F1 = 7.95, F2 = 6.68, F3 = 7.65) fell within the safe topical range of 4.5–8.0 (SNI 16-4399-1996). Carbomer's lower pH aligns with its acidic character (Syam *et al.*, 2021), while HPMC and xanthan gum are both neutral (Sammulia *et al.*, 2023; Nugrahaeni *et al.*, 2021).

Table 5. Viscosity and pH Test Results

Formula	Viscosity (mPa·s)	Requirement	pH	Requirement
F1	1,773.77	500–10,000	7.95	4.8–8.0
F2	9,725.83	500–10,000	6.68	4.8–8.0
F3	1,452.60	500–10,000	7.65	4.8–8.0

Physical Stability. Centrifugation at 3000 rpm for 30 minutes equivalent to about 10 months of storage (Sinko, 2007) produced no phase separation in any formula across all replicates (Table 6), indicating good physical stability, consistent with Ode *et al.* (2022).

Table 6. Centrifugation Test Results

Formula	Replicate 1	Replicate 2	Replicate 3
F1	Remained Homogeneous	Remained Homogeneous	Remained Homogeneous
F2	Remained Homogeneous	Remained Homogeneous	Remained Homogeneous
F3	Remained Homogeneous	Remained Homogeneous	Remained Homogeneous

CONCLUSION

Variations in HPMC, carbomer, and xanthan gum polymers affect both the physical properties and the physical stability of the 96% ethanol extract gel of fresh mahkota dewa leaves. Each polymer produced distinct homogeneity, spreadability, adhesion, viscosity, and pH characteristics: carbomer yielded the most viscous gel with the highest adhesion, HPMC produced the most neutral pH and best spreadability, and xanthan gum produced the lowest viscosity and adhesion while remaining physically stable, with none of the formulas showing phase separation after centrifugation testing.

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