Strada Journal of Pharmacy
ISSN: 2776-3544 (print); 2797-9180 (online)
Vol. 8, No 1, April 2026, pp.42-46

Formulation and Physical Quality Evaluation of *Cyperus rotundus* L. Water Fraction Gel

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ABSTRACT

The development of topical formulations derived from natural ingredients requires rigorous evaluation to ensure their safety, stability, and efficacy. This study aimed to formulate and evaluate the physical characteristics of a gel containing the water fraction of *Cyperus rotundus* L. rhizome at different concentrations. The water fraction was incorporated into gel formulations at concentrations of 5% (F1), 10% (F2), 15% (F3), and 20% (F4) using Carbopol 940 as a gelling agent. Physical evaluations included organoleptic properties, homogeneity, pH, spreadability, adhesion, and viscosity. The results showed that all formulations met acceptable physical quality standards. Increasing the concentration of the water fraction resulted in a more intense color and significantly increased pH, adhesion, and viscosity. All formulations exhibited a pH within the physiological skin range (5.53–6.80), adequate spreadability (5.49–6.77 cm), and acceptable adhesion (>2 seconds). In conclusion, the gel formulation containing the water fraction of *C. rotundus* rhizome demonstrated stable and acceptable physical characteristics and shows potential for further development as a topical phytopharmaceutical preparation..

Keywords: *Cyperus rotundus* L., Formulation, Gel, Physical Quality, Water Fraction.

INTRODUCTION

The use of medicinal plants as therapeutic alternatives continues to grow, driven by a demand for treatments with potentially fewer side effects than synthetic drugs (Hassan *et al*., 2023). One plant with significant pharmacological potential is the nut grass rhizome (*Cyperus rotundus* L.). Modern phytochemical analyses have confirmed that its rhizomes are rich in bioactive compounds, including flavonoids, tannins, and sesquiterpenes (Chen *et al*., 2021). Specifically, flavonoids from *C. rotundus* have been identified as potent anti-inflammatory agents, partly through the inhibition of key enzymes in the inflammatory pathway like cyclooxygenase-2 (COX-2) (Ali *et al*., 2022; Ahmed *et al*., 2020). For these compounds to be effective in treating localized inflammation, they must be formulated into a suitable topical delivery system (Vaibhav, *et al*., 2021).

Topical gels are a popular choice for dermal drug delivery due to their favorable characteristics. They are typically non-greasy, easy to apply, and can provide a cooling sensation, which improves patient compliance (Jones *et al*., 2019). Furthermore, their aqueous base allows for good release of hydrophilic active ingredients (Ferreira *et al*., 2021). The success of a gel formulation, however, is critically dependent on its physical properties. Parameters such as homogeneity, pH, viscosity, spreadability, and adhesion must be carefully controlled to ensure the product's stability, safety, and therapeutic performance (Hassan *et al*., 2023; Gulshan, 2016). Homogeneity ensures uniform dosage (Lee *et al*., 2022), while a physiologically compatible pH is crucial for preventing skin irritation and preserving the skin's natural acidic mantle (Schneider *et al*., 2017; Gupta *et al*., 2018). The rheological properties directly influence the feel, application, and retention time on the skin (Elham *et al*., 2025).

This research focuses on formulating a gel from the water fraction of *C. rotundus* rhizome and evaluating its physical quality. The water fraction was selected for its high polarity, which is suitable for incorporating into a hydrogel system. The objective was to assess how different concentrations of the fraction affect the physical characteristics of the gel, thereby determining its feasibility as a topical delivery vehicle.

METHODS

This research was a laboratory experimental study conducted from March to June 2025 at the Pharmaceutics Laboratory, Strada Indonesia University.

Materials and Equipment

The materials used included the water fraction of *Cyperus rotundus L.*, Carbopol 940 (pharmaceutical grade), propylene glycol (pharmaceutical grade) , nipagin (methylparaben) (pharmaceutical grade), and aquadest. The equipment used included an analytical balance (OHAUS), magnetic stirrer (Thermo Scientific), pH meter (Hanna Instruments), Brookfield viscometer (Ametek), object glass, and a spreadability test apparatus (Lloyd Instruments).

Gel Formulation

The gel was prepared by dispersing Carbopol 940 in distilled water with continuous stirring until a vortex was formed and the polymer was fully hydrated. Separately, nipagin was dissolved in hot distilled water, and propylene glycol was added as a humectant. This preservative solution was then mixed into the formed Carbopol base. Finally, the C. rotundus water fraction was incorporated at concentrations of 5%, 10%, 15%, and 20% (w/w) into the gel base and stirred until a uniform preparation was achieved (Sari *et al*., 2022; Kumar *et al*., 2019). A negative control (gel base without extract) and a positive control (commercial diclofenac gel) were also used for comparison.

Physical Quality Evaluation of the Gel

Organoleptic Test: Visual observation was conducted on the color, odor, and consistency of each gel formula.

Homogeneity Test: A small amount of the preparation was pressed between two transparent glass slides and visually inspected for the presence of aggregates or coarse particles (Lee *et al*., 2022).

pH Measurement: pH was measured using a calibrated digital pH meter. One gram of gel was dispersed in 10 mL of distilled water to form a uniform solution before measurement.

Spreadability Test: 0.5 grams of gel was placed at the center of a circular glass plate. Another plate was placed on top, and the initial diameter was recorded. A standard weight of 150 g was applied for 1 minute, and the final diameter was measured to determine the spreadability (Vaibhav *et al*., 2021).

Adhesion Test: 0.5 grams of gel was placed between two object glasses, which were then pressed together with a 1 kg weight for 3 minutes. The time required for the plates to separate under gravitational force was measured as the adhesion time (Sanjaeevani *et al*., 2025).

Viscosity Test: Viscosity was measured using a Brookfield Viscometer with a suitable spindle number 64 at a fixed rotational speed 20 rpm to determine the rheological properties of the gel (Jones *et al*., 2019).

RESULTS

All formulations exhibited acceptable physical characteristics. Increasing the concentration of the water fraction resulted in noticeable changes in color, with higher concentrations producing a deeper yellow appearance.

All formulations were homogeneous and free from visible particles. The pH values ranged from 5.53 to 6.80, indicating compatibility with skin pH. Spreadability values ranged from 5.49 to 6.77 cm, demonstrating good application properties.

Adhesion and viscosity increased with higher concentrations of the water fraction. The highest values were observed in F4 (20%), indicating improved retention on the skin.

The comprehensive results of the physical quality evaluation for all formulated gels are presented in Table 1.

Table 1. Physical Quality Evaluation Results of Water Fraction Gel

Formula	**Organoleptic (Color, Odor, Form)**	**Homogeneity**	**pH (Mean ± SD)**	**Spreadability (cm) (Mean ± SD)**	**Adhesion (s) (Mean ± SD)**	**Viscosity (cP) (Mean ± SD)**
F1 (5%)	Slightly cloudy, Characteristic odor, Semi-solid	Homogeneous	5.53 ± 0.02	5.49 ± 0.02	2.06 ± 0.02	2603.35 ± 2.05
F2 (10%)	Cloudy, Characteristic odor, Semi-solid	Homogeneous	5.55 ± 0.01	5.51 ± 0.01	2.08 ± 0.01	2604.45 ± 2.05
F3 (15%)	Yellowish cloudy, Characteristic odor, Semi-solid	Homogeneous	6.52 ± 0.02	6.48 ± 0.02	3.55 ± 0.02	3802.55 ± 2.05
F4 (20%)	Deep yellow, Characteristic odor, Semi-solid	Homogeneous	6.80 ± 0.02	6.77 ± 0.02	4.74 ± 0.02	4404.65 ± 2.10
K (-)	Clear, Base odor, Semi-solid	Homogeneous	5.52 ± 0.02	5.48 ± 0.02	2.05 ± 0.02	2602.25 ± 2.05
K (+)	Milky white, Menthol odor, Semi-solid	Homogeneous	6.82 ± 0.02	6.79 ± 0.02	4.76 ± 0.02	4406.75 ± 2.10

DISCUSSION

The successful formulation of a stable and effective herbal gel is contingent upon its physicochemical properties (Hassan, *et al*., 2023). In this study, all four gel formulas containing the water fraction of *C. rotundus* demonstrated acceptable physical characteristics. The organoleptic properties showed a concentration-dependent color change, which is a common and acceptable trait in herbal formulations due to natural pigments (Sari *et al*., 2022). All formulas were visually homogeneous, indicating that the Carbopol 940 polymer network successfully entrapped and uniformly dispersed the plant fraction, a critical factor for consistent product performance (Lee *et al*., 2022).

The pH of all formulations (5.53–6.80) fell within the acceptable physiological range of the skin (typically 4.5–6.8), which is vital for minimizing the risk of irritation and maintaining the integrity of the skin's acid mantle (Gupta *et al*., 2018; Schneider *et al*., 2017). The spreadability of all formulas was within the desirable range of 5–7 cm, indicating ease of application and uniform coverage over the target area.

A key finding was the concentration-dependent increase in adhesion. The F4 formula (4.74 s) showed adhesion comparable to the positive control, suggesting prolonged residence time on the skin. Enhanced bioadhesion is directly linked to improved therapeutic outcomes by increasing the contact duration for drug absorption (Singh *et al*., 2021). This property is closely related to the viscosity of the preparation. As the concentration of the fraction increased, the viscosity also rose, likely due to greater interaction between the dissolved solids and the gelling agent. The rheological profile of a gel not only affects its adhesion but also its feel and release kinetics, making it a critical parameter for patient-centric design (Jones *et al.*, 2019; Rita *et al* , 2023). The observed viscosity values suggest a robust formulation that can maintain its structure while allowing for effective application.

CONCLUSION

The water fraction of *Cyperus rotundus* L. rhizomae can be successfully formulated into a stable gel with acceptable physical characteristics. All formulations met the required parameters for topical preparations. Increasing the concentration improved viscosity and adhesion, enhancing the formulation's potential effectiveness. Further studies, including stability testing and in vivo evaluation, are recommended.

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