Natural Bioactive-Loaded Hydrogel Patch for Cosmetic Applications

Premika Sankanut[1], Panida Suphiratwanich[2], Nachtharinee Laosirisathian[2] and Kanchana Dumri[1]*

[1] Division of Biochemistry and Biochemical Innovation, Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand

[2] Faculty of Pharmacy, Payap University, Chiang Mai 50000, Thailand

***Corresponding author email : kanchana.d@cmu.ac.th**

ABSTRACT

Hydrogel-based delivery systems have attracted increasing interest in functional cosmetics due to their high hydration capacity, biocompatibility, and ability to provide localized delivery of bioactive compounds. This study developed carrageenan–gellan gum hydrogel patches incorporating berberine chloride (BC) and niacinamide and successfully generated a scalable cosmetic prototype. The formulations were evaluated for physicochemical properties, antioxidant activity, moisture retention, and preliminary dissolution behavior. Berberine chloride exhibited antioxidant activity with an IC_{50} of 1.17 mg/mL 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay, which guided formulation optimization to ensure sufficient antioxidant availability following dissolution from the polymer matrix. UV–visible spectrophotometric analysis identified characteristic maximum absorption wavelengths (λ_{max}) at 349 and 429 nm for Berberine chloride and 261 nm for Niacinamide. These wavelengths were employed to monitor in vitro dissolution and quantify percentage dissolution using validated calibration curves. Three formulations were prepared: F0 (blank), F1 (berberine chloride), and F2 (berberine chloride + niacinamide). All demonstrated skin-compatible pH and maintained physical stability after storage at 4 °C and room temperature (27 ± 2 °C) for 21 days. F2 exhibited a slower dissolution rate, likely due to enhanced polymer network interactions. The developed prototype demonstrates strong potential for further optimization and translation into commercially viable cosmetic products.

INTRODUCTION

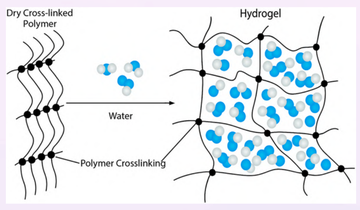


Figure 1 Hydrogel

Hydrogel

- Hydrogels are hydrophilic polymer networks capable of absorbing large amounts of water.
- They can be fabricated as beads, fibers, or hydrogel patches.
- They enable controlled release of active compounds.



Figure 2 Berberine Chloride Powder

Berberine Chloride Powder

- Berberine is a natural yellow alkaloid derived from the plant *Berberis vulgaris L.*
- It is mainly found in the roots and bark.
- It exhibits antioxidant and anti-inflammatory properties.

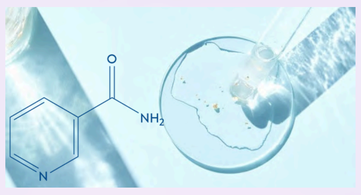


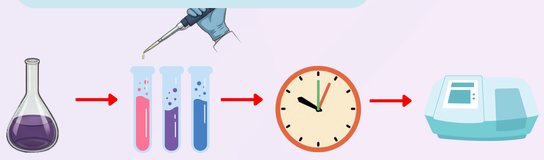
Figure 3 Niacinamide

Niacinamide

- Niacinamide is a water-soluble form of Vitamin B_3.
- It is widely used in cosmetic formulations.
- It helps strengthen the skin barrier and reduces hyperpigmentation.

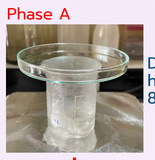
METHODOLOGY

Antioxidant Activity by DPPH Assay



Antioxidant activity was evaluated using the DPPH radical scavenging assay, and IC_{50} values were determined by UV–Vis spectrophotometry.

Hydrogel patch formulation

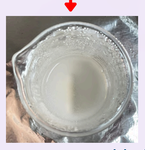


Phase A

DI water was heated to 80–90 °C.

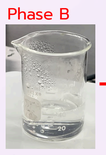


Gellan gum was added.



Carrageenan was added. The mixture was cooled to 50–60 °C, then glycerin was added.

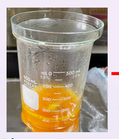
Phase B



DI water was heated to 50-60 °C.



All active ingredients were added to the mixture.



Phase A was combined with Phase B, then the preservative was added.

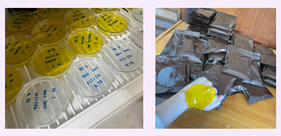


Final Product

Evaluation of the Hydrogel Patches

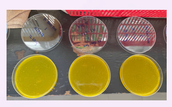
The developed hydrogel patches were evaluated for physical appearance and stability, and the *in vitro* release of active compounds was assessed to determine the release profile.

1. Physical and Stability



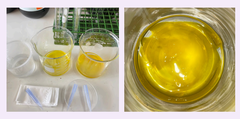
- Hydrogel patches were stored at 4 °C and room temperature (27 ± 2 °C).
- Storage period: 21 days.
- Physical stability was evaluated.
- Appearance, color, and texture were monitored.

2. Moisture Loss



- Moisture loss was evaluated by measuring weight change of hydrogel patches.
- Percentage weight loss was calculated.
- Water retention capacity was assessed.

3. Dissolution



- A preliminary dissolution study was conducted.
- Initial release of active compounds from hydrogel patches was observed.
- The ability of the formulation to retain and release active ingredients was assessed.

F0 : Hydrogel base only
F1 : Berberine chloride - loaded formulation
F2 : Berberine chloride + niacinamide loaded formulation

Based on the IC_{50} results, the selected concentration of active compounds was incorporated into the hydrogel base. The polymer solution was prepared, mixed with the active ingredients, and cast into molds to form hydrogel patches.

Batch 25 g = 100 %	Phase A				Phase B		
Formulas/Ingredients	**Di Water A**	**Carrageenan**	**Gellan gum**	**Glycerin**	**Di Water B**	**Berberine Chloride**	**Niacinamide**
Formula 0	93.2%	1.5%	0.3%	5%	-	-	-
Formula 1	71%	1.5%	0.3%	5%	20%	0.2%	-
Formula 2	68%	1.5%	0.3%	5%	20%	0.2%	3%

Table 1 Formulation of Hydrogel Patches

RESULTS and DISCUSSION

Antioxidant Activity by DPPH Assay



Figure 4 DPPH radical scavenging activity of Berberine Chloride

Berberine Chloride IC_{50} = 1.17 mg/ml

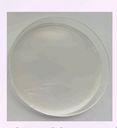


Figure 5 DPPH radical scavenging activity of Vitamin C (Standard)

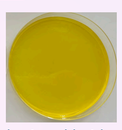
Vitamin C (Standard) IC_{50} = 0.008 mg/ml

- Berberine chloride contains bioactive compounds with reported antioxidant and anti-inflammatory activities.
- Therefore, antioxidant activity was selected for evaluation.
- The activity was determined using the DPPH assay and expressed as IC_{50} values.
- IC_{50} of berberine chloride was compared with vitamin C as a reference antioxidant.

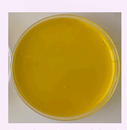
Physical and Stability



F0 : Hydrogel base only



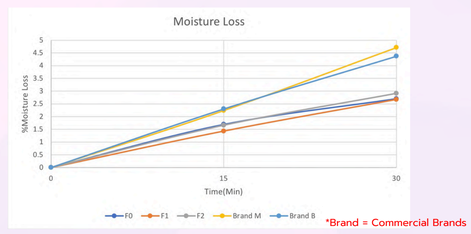
F1 : Berberine chloride only



F2 : Berberine chloride + niacinamide

- The stability study evaluated the physical characteristics of the hydrogel patches during storage.
- Over 21 days, the patches maintained a smooth surface, soft texture, and normal elasticity with no visible changes.
- The formulation remained physically stable at 4°C and room temperature (27 ± 2°C), indicating acceptable short-term stability.

Moisture Loss



*Brand = Commercial Brands

Figure 6 Moisture Loss Content

- Moisture loss was evaluated to determine the water retention ability of the hydrogel.
- The developed hydrogel showed <5% water loss within 30 minutes, meeting the general hydrogel criterion.
- This results indicated the good moisture retention and suitability for skin application.

Dissolution

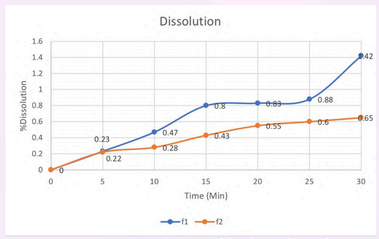


Figure 7 Dissolution of hydrogel patch

- A preliminary dissolution study was performed to evaluate the release of active compounds from the hydrogel patch.
- The results showed gradual release over time, indicating the potential of the hydrogel matrix as a delivery system.
- However, further optimization may be required to achieve better controlled release.

F1. : Berberine chloride only
F2 : Berberine chloride + niacinamide

CONCLUSION

- The samples exhibited concentration-dependent antioxidant activity, and the IC_{50} value was used to select the appropriate formulation concentration.
- The developed hydrogel patches showed acceptable short-term physical stability under the tested storage conditions.
- Moisture loss results indicated adequate water retention capacity.
- Preliminary dissolution testing confirmed the release of active compounds from the hydrogel matrix.
- Further optimization is recommended to improve formulation performance.

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