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Formulation and Evaluation of *Portulaca grandiflora* Ethanolic Extract Herbal Transdermal Patches for Diabetic Wound Management

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Abstract: This study successfully created, analyzed, and assessed a new herbal polymeric transdermal patch that integrates an ethanolic extract from *Portulaca grandiflora*, aimed at enhancing the management of wound healing in diabetes. Initial phytochemical analysis confirmed a significant presence of various bioactive compounds such as flavonoids, phenols, alkaloids, saponins, and tannins, with the highest total flavonoid concentration noted at 200 µg/mL. The transdermal patches were meticulously produced using the solvent-casting technique with a polymer blend made up of sodium alginate and sodium carboxymethyl cellulose. Thorough physicochemical assessments affirmed excellent mechanical and barrier characteristics, including consistent weight distribution, suitable thickness, high folding endurance, surface pH, and structural robustness. Additionally, in vivo studies conducted with a streptozotocin-induced diabetic rat model indicated that the application of the developed patches significantly sped up wound healing, lowered elevated blood plasma glucose levels, and helped maintain stable body weight in comparison to the untreated control group. Importantly, the higher dosage of 400 mg/kg showed enhanced, dose-related therapeutic effects. These findings highlight the substantial combined anti-diabetic and wound-healing capabilities of *Portulaca grandiflora* herbal transdermal delivery systems for superior therapeutic purposes.

Keywords: *Portulaca grandiflora*, Transdermal patch, Diabetic wound healing, Phytochemical screening, Sodium alginate, Streptozotocin-induced diabetes

INTRODUCTION

A wound refers to an injury or alteration to the typical anatomical arrangement and role of the tissue. It can vary from a minor disruption in the skin's outer layer to a more serious injury that affects the dermis, potentially extending into the underlying tissue and harming additional structures like muscles, blood vessels, and organs (such as the lungs, intestines, and cornea). Moisture-retentive dressings (MRDs) are commonly used in clinical studies, particularly for chronic wounds, and their positive effects have been established. Negative-pressure therapy serves as another method for treating wounds. Nanoparticles that possess inherent antimicrobial features, along with those acting as carriers for antibiotics or other antimicrobial substances, play a significant role in diminishing the microbial presence in wounds. A variety of phenotypes have been noted, with flower colors varying from white to dark yellow, orange, red, magenta, and light yellow. In traditional oriental medicine, ailments such as sore throat, skin rashes, and inflammation are alleviated by *Portulaca grandiflora*, which is also utilized as a topical treatment for snake bites, insect stings, burns, scalds, and eczema. The extracts from *Portulaca grandiflora* have been linked to antioxidant and antifungal effects. It has shown a broad range of antimicrobial properties, and reports indicate anticancer, antidiabetic, and anti-Parkinson's effects. Various phytoconstituents, including

flavonoids, alkaloids, glycosides, phenolic compounds, saponins, tannins, and triterpenoids, have been discovered in this botanical species. The properties of *Portulaca grandiflora* encompass antioxidant, antibacterial, and antidiabetic functions. Its efficacy in promoting wound healing has been validated through experimental research. As a result, this plant is regarded as a potentially valuable herbal resource for diabetic wound management.

The taxonomical position of *Portulaca grandiflora* Hook. can be summarized as follows:

- Kingdom: Plantae
- Order: Caryophyllales
- Family: Portulacaceae
- Genus: *Portulaca*
- Species: *Portulaca grandiflora* Hook.



Portulaca grandiflora

Pharmacological studies

Portulaca grandiflora extract in diabetic rats induced by streptozotocin. The extract notably lowered glucose levels in the blood and increased body weight following 21 days of administration. The researchers concluded that *P. grandiflora* has potential antidiabetic properties (Devi et al. 2019). *Portulaca grandiflora*. This investigation centered on the extraction and recognition of naturally occurring betaxanthin pigments found in the vibrant blossoms of the plant. Two betalain compounds, identified as portulacaxanthin II and portulacaxanthin III, were documented. The research revealed that the flowers of *P. grandiflora* contain chemically unique betalain pigments and underscored the phytochemical variety within this species. These results lay the groundwork for more in-depth studies into the biological attributes of its floral components (Trezzini and Zryd 1991). *Portulaca grandiflora* mutants. The scientists examined various plant genotypes and measured their contents of flavonoids and phenolics, alongside assessing antioxidant activity via the DPPH radical-scavenging test (Nurcholis et al. 2023). Initial phytochemical analyses suggested the existence of several bioactive components, while the experimental results indicated possible antidiabetic effects. The authors concluded that the extract of *P. grandiflora* may include bioactive compounds that could have positive effects in experimental diabetes, recommending further research to confirm its therapeutic capacities (Devi et al. 2019). Various flower-color types were assessed for their flavonoid content and their effects on wound healing in an experimental model of animal wounds. The findings revealed variances in flavonoid content and wound-healing abilities among the explored varieties (Budiawan et al. 2023). The in-vitro antioxidant capacity and GC-MS profile of *Portulaca grandiflora* Hook were compared to that of *Portulaca oleracea* L. This research assessed the antioxidant potential of the plant extracts and identified their chemical components through chromatographic techniques (Ao 2019). The wound-healing effects were analyzed using a chemically induced diabetic foot ulcer model in rats. Additionally, human skin fibroblast cells (Hs27), human umbilical vein endothelial cells (HUVEC), and mouse macrophage cells (RAW264. 7) were utilized to investigate tissue regeneration, angiogenesis, and anti-inflammatory effects, respectively (Tam et al. 2011). The wound-healing properties of the n-hexane extract of *Portulaca grandiflora* were evaluated through both in vitro and in vivo models. The extract fostered cell migration and facilitated wound closure in the scratch assay. In vivo, the ointment contributed to epidermal closure, re-epithelialization, and granulation tissue development. The authors concluded that the phytochemicals present in *P. grandiflora*, particularly terpenoids and steroids, may aid in wound healing (Mus'hib et al. 2024). Diabetic sores pose significant medical difficulties marked by

hindered healing and extended inflammation, requiring sophisticated delivery mechanisms that are specifically aimed. This study effectively creates and assesses a new herbal transdermal patch that integrates *Portulaca grandiflora* ethanolic extract into a matrix composed of sodium alginate and sodium carboxymethyl cellulose polymers. In vivo testing conducted with a rat model of diabetes induced by streptozotocin shows that these engineered patches notably speed up the wound healing process and lower blood sugar levels in a manner that correlates with dosage.

MATERIAL AND METHODS

Collection of samples:

Portulaca grandiflora collected from Yazhini Biotech Laboratory, Srivilliputhur, Tamil Nadu for this investigation.

MATERIAL:

1. Ethanol extraction: *Portulaca grandiflora* whole plant powder

Ethanol

2. Hot water extraction: *Portulaca grandiflora* whole plant powder Distilled water

3. Transdermal patch preparation:

- *Portulaca grandiflora* whole plant ethanol extract
- Sodium Carboxymethyl Cellulose
- Sodium Alginate
- Polyethylene Glycol 400
- Glycerol
- Tween 80
- Distilled water

GLASSWARES AND INSTRUMENTS:

Soxhlet Apparatus, Round bottom flask, Beaker, Magnetic stirrer, Test tube, Funnel, Pipette, Petridish, Conical flask, Heating mandle, Measuring cylinder

PREPARATION OF PLANT EXTRATION:

Collection and drying:

The fresh whole plant of *Portulaca grandiflora* was collected from a nearby area during a suitable season. The plant was identified and authenticated based on its morphological characters. The collected plant material was washed thoroughly with distilled water to remove dirt and other impurities. The collected plant parts were shade-dried at room temperature for several days until completed drying. The dried plant material was then powdered using a suitable grinder. The powdered material was stored in an airtight container in a cool and dry place for further experimental studies.

1) Preparation of Hot Water Extract (Aqueous extract):

5 g of dried, finely powdered plant material of *portulaca grandiflora* was taken. The plant material was placed in a beaker, and 200 ml of distilled water was added. The mixture was boiled on a hot plate with continuous stirring at 30° – 40° C for 45 minutes. The aqueous extract was filtered through Whatman No.1 filter paper, and the filtrate was collected for further analysis. The filtrate was stored in a refrigerator at 4° C until further use.

2) Preparation of Ethanolic Extract using Soxhlet Apparatus:

A weighed quantity of 25 g of powdered *Portulaca grandiflora* was subjected to hot continuous extraction in a Soxhlet apparatus using 250 mL of ethanol as the solvent. The extraction was continued for 2 days or until the solvent in the thimble became colourless. The extract obtained was dried at room temperature. The percentage yield was determined. The dried extract was stored in an airtight container for further use.

FORMULATION OF HERBAL TRANSDERMAL PATCHES:

The herbal transdermal patch containing ethanolic extract of *Portulaca grandiflora* was prepared by the solvent casting method, based on previously reported sodium alginate-sodium carboxymethyl cellulose (Na-CMC) polymer blend film formation. Sodium alginate and sodium carboxymethyl cellulose (Na-CMC) were selected as film-forming polymers, while glycerol was used as a plasticizer, and Tween 80 and polyethylene glycol 400 (PEG-400) were incorporated as formulation excipients.

Preparation of polymer solution:

Sodium alginate and sodium carboxymethyl cellulose were separately dissolved in deionized water to prepare 2% w/w polymer solutions. Each solution was mixed continuously until a uniform and lump-free dispersion was obtained. The prepared polymer solutions were then blended in a 60:40 ratio of sodium alginate to sodium carboxymethyl cellulose and mixed thoroughly to obtain a homogeneous polymeric solution.

Incorporation of herbal extract and excipients:

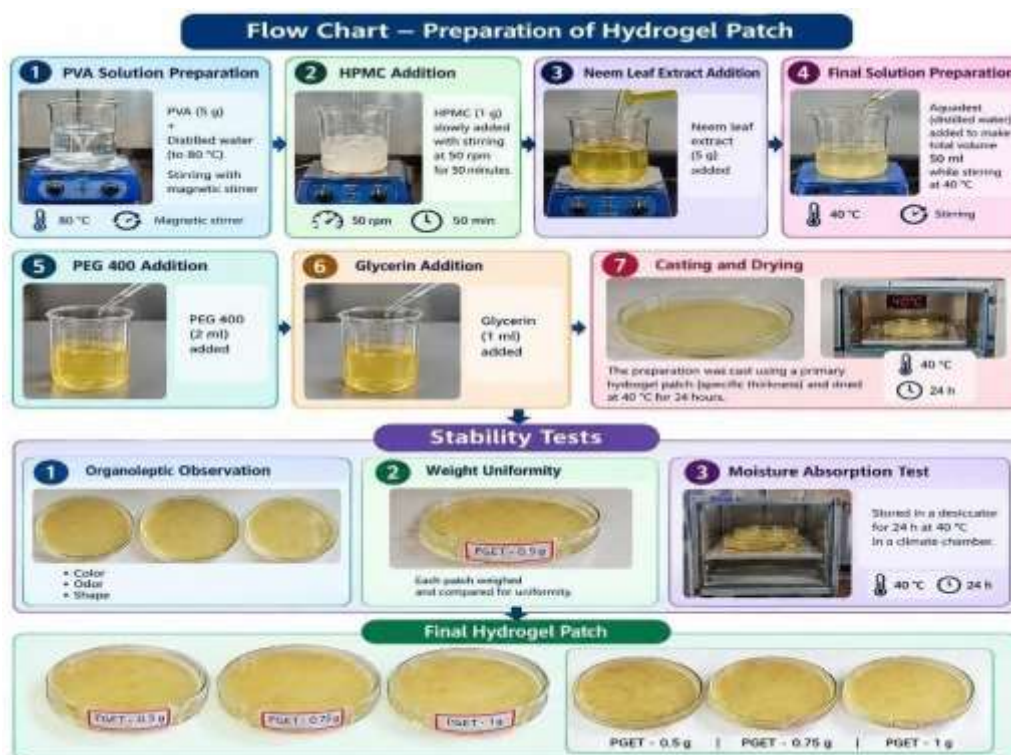
Glycerol was added to the polymeric blend to improve the flexibility of the formed film. Tween 80 and polyethylene glycol 400 were subsequently incorporated and mixed uniformly. The required quantity of ethanolic extract of *Portulaca grandiflora* was then added to the polymeric mixture and continuously mixed until a homogeneous herbal formulation was obtained.

Microwave treatment and solvent casting:

The prepared polymeric formulation was subjected to microwave treatment at 500 W for the predetermined treatment period (1 min-3 min). After microwave treatment, the formulation was allowed to settle until the entrapped air bubbles were reduced. A measured quantity of the bubble-free formulation was then transferred into a clean petri dish and uniformly spread to obtain a film of consistent thickness.

Drying and storage of transdermal film:

The cast formulation was dried in a hot air oven at 40°C for 72 hours or until complete dryness was achieved. The dried film was carefully removed from the petri dish and inspected for uniformity and physical appearance. The prepared herbal transdermal patches were then stored in a desiccator until further evaluation.



Formulation of different patches:

S.NO	INGREDIENTS	F1	F2	F3
1.	Sodium alginate	2g	2g	2g
2.	Sodium carboxymethyl cellulose	2g	2g	2g
3.	Portulaca grandiflora ethanolic extract	0.5g	0.75g	1.0g
4.	Glycerol	2g	2g	2g
5.	Tween 80	0.1g	0.1g	0.1g
6.	Polyethylene glycol 400	0.05g	0.05g	0.05g
7.	Deionized water	Quantity sufficient to 100g	Quantity sufficient to 100g	Quantity sufficient to 100g

Evaluation of Transdermal Patch**Physical appearance:**

All prepared patches were visually inspected for color, clarity, flexibility, and smoothness.

Thickness of the patch:

The thickness of patches was measured at six different points using a digital micrometer and three randomly selected patches were used for each formulation. (28)

Uniformity of weight:

A weight variation test was performed on the patches by weighing them on a digital weighing machine. Determinations were carried out in triplicate for each formulation. The average weight and standard deviation values were then calculated. (27)

Folding endurance:

The test was carried out to assess the efficiency of the plasticizer and the strength of patches prepared using different polymers. Folding endurance was defined as the number of folds required to break a polymeric patch. Folding endurance was measured manually by repeatedly folding a small strip of the film (2 × 2 cm) at the same place until it broke. The number of times the patch could be folded at the same place without breaking or cracking provided the value of folding endurance. Three patches of each type were taken for the test. (27)

Flatness study:

Longitudinal strips were cut from the prepared patch, the length of each strip was measured, and the variation in length due to non-uniformity in flatness was then measured. Flatness was calculated by measuring the constriction of the strips, and 0% constriction was considered to represent 100% flatness.

Percentage of moisture content:

This test was also carried out to check the integrity of the films under dry conditions. The individual transdermal films (of the specified area) were kept in a desiccator containing fused anhydrous calcium chloride at room temperature. During this period, the films were weighed at regular time intervals of 24, 48, and 72 h.

The percentage moisture content was determined using the following formula:

$$\% \text{ Moisture content} = (\text{Initial weight} - \text{Final weight}) / \text{Initial weight} \times 100.$$

Percentage of moisture uptake:

Each film was weighed accurately and was placed in a desiccator containing 200 mL of a saturated potassium chloride solution (84% relative humidity) at room temperature. After 3 days, the films were removed and weighed. The percentage of moisture uptake was calculated as the difference between the final and initial weights with respect to the initial weight.

Surface pH:

Patches were kept in contact with 0.5 mL of double-distilled water in glass tubes for 1 h and were allowed to swell. A combined glass electrode was brought near the surface of the patch, and pH readings were taken after an equilibration period of 1 min.

Water vapor transmission:

Water vapor transmission rate (WVTR) was defined as the quantity of moisture transmitted through a unit area of film in unit time. Glass vials of equal volume and diameter were used as transmission cells. The cells were washed thoroughly and dried in an oven. Approximately 1 g of anhydrous fused calcium chloride was placed in each vial, and the patch was fixed over the brim of the vial with adhesive tape. The vials were then weighed and were placed in desiccators containing a saturated potassium chloride solution to maintain 84% relative humidity. The cells were removed from the desiccators and were weighed after the 1st, 2nd, 3rd, 4th, 5th, 6th, and 7th days. The water vapor transmission rate was determined as follows: $WVTR = W L / S$, where W is the weight of water vapor transmitted, L is the thickness of the patch, and S is the surface area exposed in square centimeters.

IN VIVO STUDY

Animals:

Female albino Wistar rats were used in wound healing and diabetic studies. All animals were supplied by and kept in the Laboratory Animal Service Centre, The Chinese University of Hong Kong. They were housed under the conditions of 22–25°C and a 12-h light-dark cycle. They were supplied with standard animal chow (Pico Lab Rodent Diet 20, PMI Nutrition International, Inc., USA), and tap water was constantly supplied to the animals. All animal studies were performed according to the institutional rules concerning animal experiments (CUHK-AEEC animal experimentation ethics approval nos.: 07/084/MIS and 08/003/MIS).

In vivo diabetic wound healing study:

A chemically induced diabetic wound model was employed to evaluate the anti-diabetic and wound-healing activity of TAPE. Diabetes was induced in Wistar rats by intraperitoneal administration of streptozotocin (STZ) at 70 mg/kg body weight. After induction, blood glucose levels were measured, and rats with plasma glucose levels ≥ 250 mg/dL were considered diabetic. The diabetic rats were divided into five experimental groups:

Group I – Normal Control, Group II – Disease Control (STZ), Group III – Standard (Glimepiride), Group IV – TAPE 200 mg/kg, and Group V – TAPE 400 mg/kg. A standardized full-thickness excision wound was created on the dorsal surface of the right hind foot under suitable anesthesia. Wound size was measured on the following day and considered as Day 0. Treatment was then administered to the respective groups for 7 consecutive days. The normal control group received the vehicle, while the disease-control group received STZ-induced diabetic treatment without the test formulation.

The standard group received glimepiride, whereas the treatment groups received TAPE at 200 and 400 mg/kg body weight, respectively. On Day 8, wound area, plasma glucose level, and body weight were recorded to assess the anti-diabetic and wound-healing effects of TAPE.

Group	Animal model	Treatment	Purpose
G1 – Normal control	Non-diabetic + wound	No active treatment / vehicle	Normal wound healing
G2 – Diabetic control	Diabetic + wound	No active treatment	Shows impaired diabetic wound healing
G3 – Standard control	Diabetic + wound	Standard wound- healing treatment	Positive control

G4 – Blank patch	Diabetic + wound	Patch without plant extract	Determines effect of patch material itself
G5 – PG extract patch – Low dose	Diabetic + wound	Low-dose <i>P. grandiflora</i> extract patch	Tests lower dose
G6 – PG extract patch – High dose	Diabetic + wound	High-dose <i>P. grandiflora</i> extract patch	Tests higher dose

1. Experimental Animals:

- Female albino Wistar rats were used as experimental animals.
- Animals were housed under controlled laboratory conditions with a 12 h light/12 h dark cycle and a temperature of 22–25°C.
- Standard rodent diet and drinking water were provided ad libitum.
- Body weight was monitored weekly throughout the experimental period.
- The experimental protocol was conducted after obtaining approval from the appropriate institutional animal ethics committee.

2. Induction of Type-2 Diabetes Mellitus:

- Type-2 diabetes was induced using the neonatal streptozotocin (n5-STZ) model.
- Five-day-old Wistar rats were administered streptozotocin (70 mg/kg, intraperitoneally).
- STZ was freshly prepared in 0.1 M citrate buffer (pH 4.5) before administration.
- Control animals received an equivalent volume of citrate buffer.
- Animals were subsequently maintained until adulthood for development of the diabetic condition.

3. Confirmation of Diabetes:

- Approximately 9 weeks after STZ administration, blood glucose levels were determined using blood obtained from the tail tip.
- A glucometer was used for blood glucose estimation.
- Rats showing blood glucose levels of ≥ 300 mg/dL were considered severely diabetic and selected for the foot-wound experiment.

4. Induction of Full-Thickness Foot Wound:

- On Day 0, diabetic rats were anesthetized with ketamine (75 mg/kg) and xylazine (10 mg/kg) intraperitoneally.
- The skin of the right hind footpad was carefully shaved and disinfected with 70% ethanol.
- A rectangular full-thickness excisional wound measuring 2 mm $\times$ 5 mm was created on the right hind footpad using a sterile scalpel.
- The wound was allowed to heal naturally and was subsequently evaluated at predetermined time points.

5. Experimental Time Points:

- Day 0: Foot wound induction.
- Day 2: Initial wound-area measurement and baseline assessment.
- Day 4: Blood glucose and blood-perfusion assessment.
- Day 6: Wound-area assessment and evaluation of the proliferative/angiogenic phase.
- Day 8: Final wound-related assessments and tissue collection

6. Measurement of Wound Area:

- The wound was photographed together with a metric ruler containing standardized 1 × 1 cm reference squares.
- Digital images were obtained under standardized lighting conditions.
- The wound area was calculated using calibrated SPOT 3.5.5 image-analysis software.
- Wound healing was evaluated based on the reduction in wound area over time.

7. Blood Glucose Estimation:

- Blood glucose levels were monitored at predetermined intervals following wound induction.
- Blood samples were obtained from the tail tip.
- A Contour Plus glucometer was used for glucose estimation.
- Changes in blood glucose were recorded throughout the wound-healing period.

8. Assessment of Blood Perfusion:

- Blood perfusion of the wounded foot was evaluated using a Laser Doppler Imaging system.
- The wounded foot was positioned appropriately and scanned using the repeat-image measurement mode.
- The corresponding unwounded foot was used as an internal control.
- Perfusion data were recorded as flux values and analyzed using the appropriate imaging software.

9. Estimation of C-Reactive Protein (CRP):

- Blood samples were collected under general anesthesia before euthanasia.
- Serum was separated by centrifugation.
- Serum CRP levels were determined using a rat C-reactive protein ELISA kit according to the manufacturer's instructions.
- CRP was used as an indicator of systemic inflammation.

10 Statistical Analysis:

- Experimental data were expressed as mean ± standard deviation (SD).
- Differences between experimental groups and time points were analyzed using appropriate statistical tests, including two-way ANOVA followed by Bonferroni post-hoc analysis.
- Statistical significance was considered at $P < 0.05$.

RESULTS

Phytochemical studies:

Initial phytochemical analysis of the Ethanolic extract from *Portulata grandiflora* (PGET) has revealed the presence of flavonoids, phenols, alkaloid, protein, saponin, tannin and carbohydrate. Initial phytochemical analysis of the aqueous extract from *Portulata grandiflora* (PGAE) has revealed the presence of flavonoids, phenols, alkaloids, saponins, tannins, and carbohydrates.

Table 1: Phytochemical studies

S.No	Phytochemical Test	Ethanol extract	Aqueous extract
1.	Alkaloids	+	+
2.	Flavonoids	+	+
3.	Phenols	+	+
4.	Proteins	+	-
5.	Saponin	+	+

6.	Carbohydrate	+	+
7.	Tannin	+	+

Ethanol

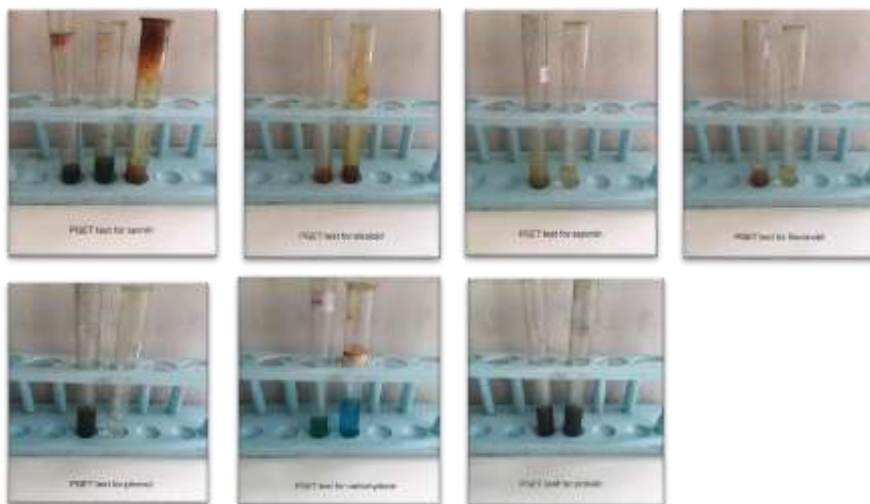


Fig 1: Phytochemical studies

Aqueous

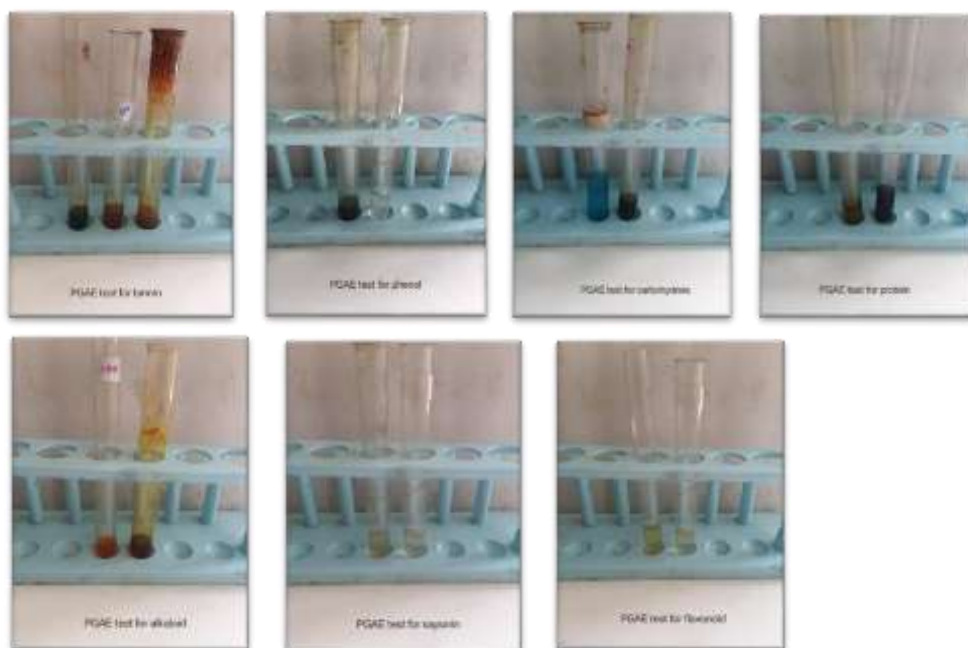


Table 2: Total Flavonoids content of portulaca grandiflora ethanolic extract

S. NO	Concentration	OD	Average	Total flavonoids
1	100	0.04	0.05	71 mg
2		0.06		

3		0.05		
1	200	0.09	0.08	88 mg
2		0.09		
3		0.08		
1	300	0.09	0.09	81 mg
2		0.09		
3		0.10		
Quercetin (Standard)				
1	100	0.07	0.07	
2		0.08		
3		0.08		
1	200	0.09	0.09	
2		0.10		
3		0.10		
1	300	0.12	0.11	
2		0.12		
3		0.11		

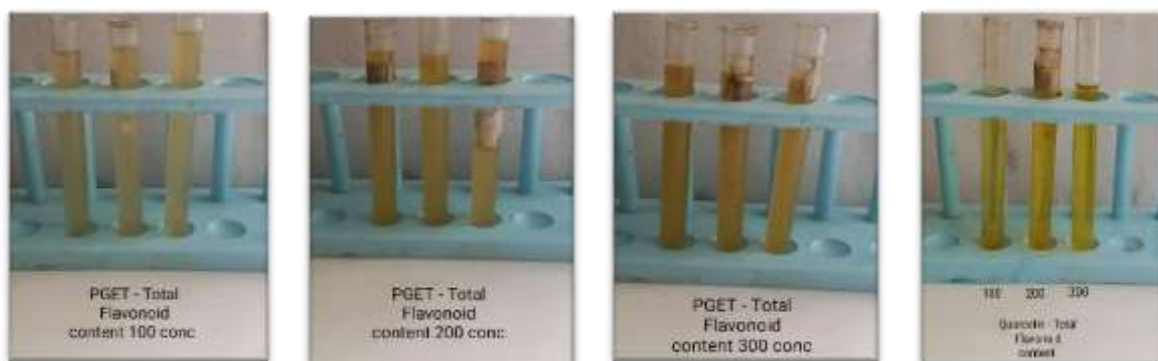
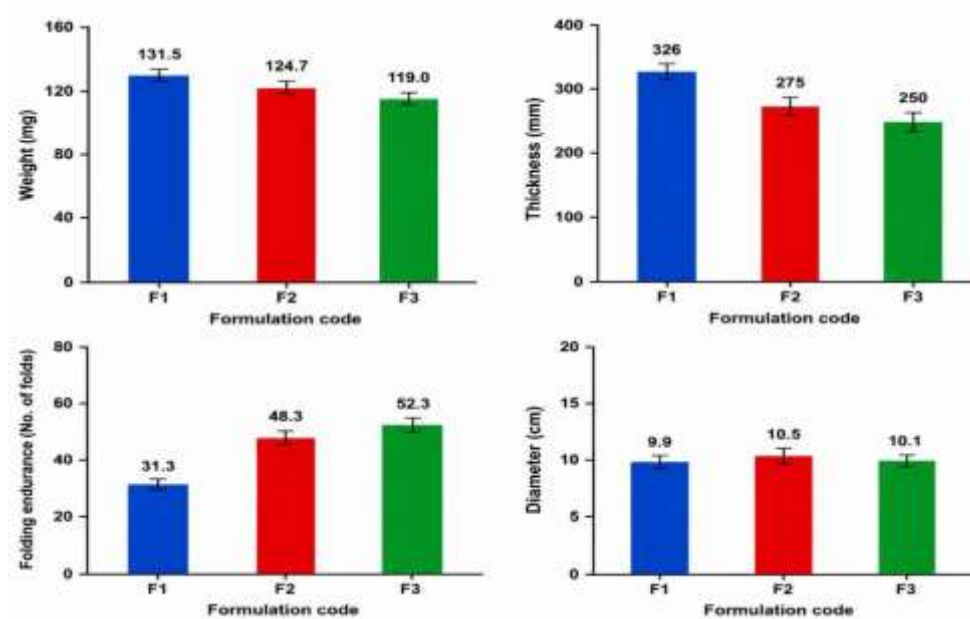


Fig 2: Test Standard

Table 3: Composition and Physicochemical Properties of Protulaca grandiflora Transdermal Patches

Formulation	Weight (mg) $\pm$ Sd	Thickness (mm) $\pm$ sd	Folding Endurance $\pm$ sd	Diameter (cm) $\pm$ sd	Area (cm) ²	Flatness (%)
F1	131.5 $\pm$ 5.27	326 $\pm$ 6.53	31.3 $\pm$ 3.01	9.9 $\pm$ 0.59	12.56	100
F2	124.7 $\pm$ 4.56	275 $\pm$ 6.36	48.3 $\pm$ 4.50	10.5 $\pm$ 0.39	13.19	100
F3	119.0 $\pm$ 4.08	250 $\pm$ 4.12	52.3 $\pm$ 2.51	10.1 $\pm$ 0.28	13.51	100

**Fig 3:** Composition and Physicochemical Properties of Protulaca grandiflora Transdermal Patches**Table 4: Effect of Drug on Wound Healing of Diabetic Rats**

Parameter	Day	Normal Control (n=6)	Disease Control (STZ) (n=6)	Glimepiride (n=6)	PGTP 200 mg/kg (n=6)	PGTP400 mg/kg (n=6)
Wound area (mm ²)	0	20.6 $\pm$ 1.2	21.4 $\pm$ 1.5	21.2 $\pm$ 1.3	21.5 $\pm$ 1.4	21.3 $\pm$ 1.2
	8	4.2 $\pm$ 0.8	13.8 $\pm$ 1.6	5.1 $\pm$ 0.9**	8.3 $\pm$ 1.1*	6.0 $\pm$ 0.9**
Plasma glucose (mg/dL)	0	98.5 $\pm$ 5.2	382.6 $\pm$ 18.4	379.8 $\pm$ 17.9	385.2 $\pm$ 19.1	381.4 $\pm$ 18.7
	8	101.2 $\pm$ 5.5	391.8 $\pm$ 19.2	218.6 $\pm$ 12.7**	286.4 $\pm$ 15.3*	241.8 $\pm$ 13.6**

Body weight (g)	0	246.8±8.4	244.5 ± 9.1	245.7 ± 8.7	243.8 ±9.3	245.1 ±8.9
	8	250.6±8.7	232.4 ± 9.8	247.9 ±8.5**	240.2 ± 9.1*	244.8 ± 8.6**

Values are expressed as mean ± SEM, n=5, p<0.05, and **p<0.01 versus disease control (STZ group).

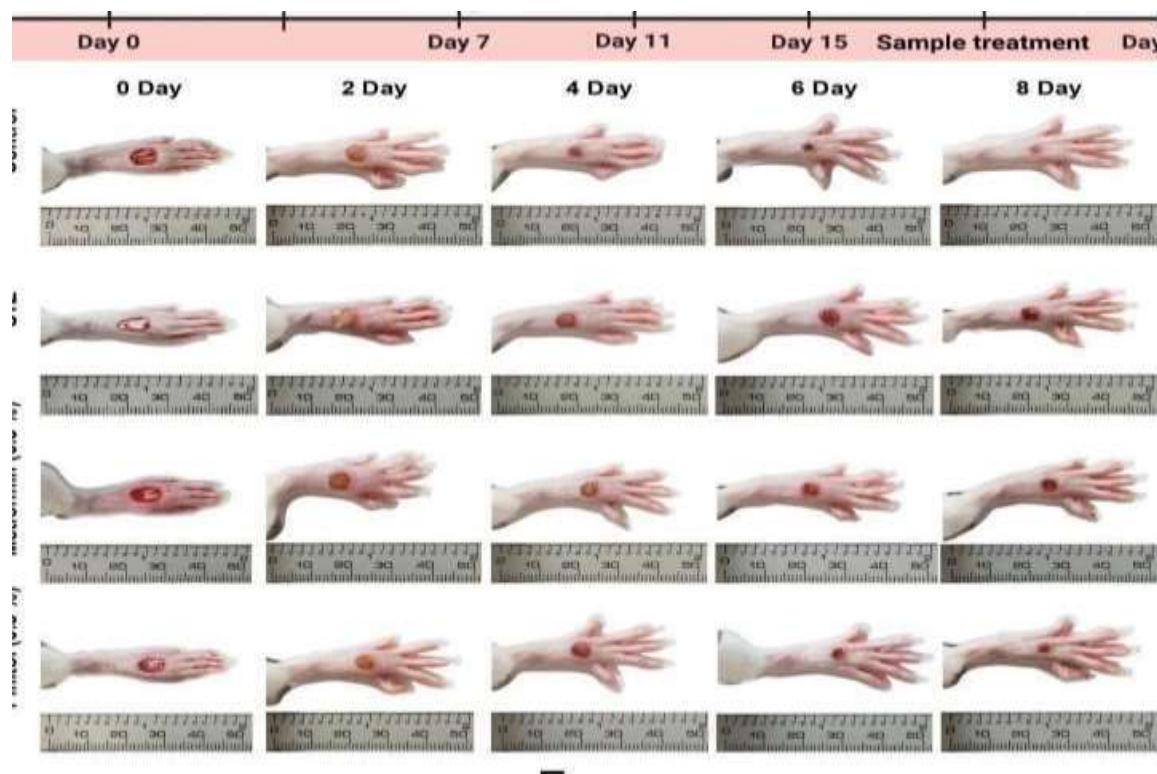


Fig 4: Effect of Drug on Wound Healing of Diabetic Rats

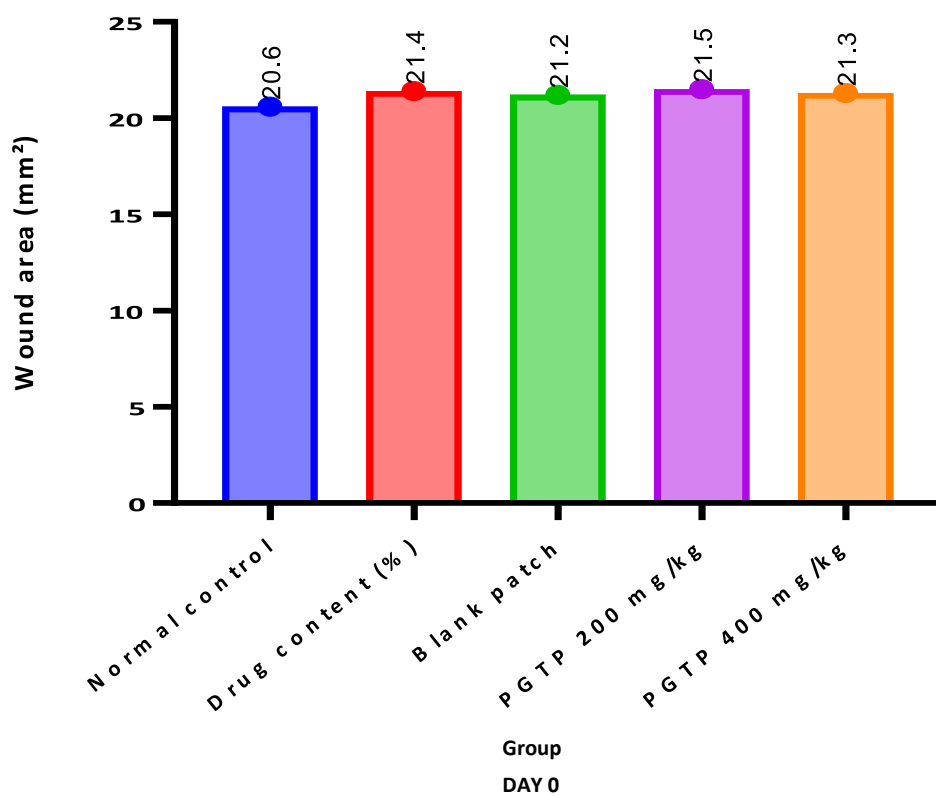
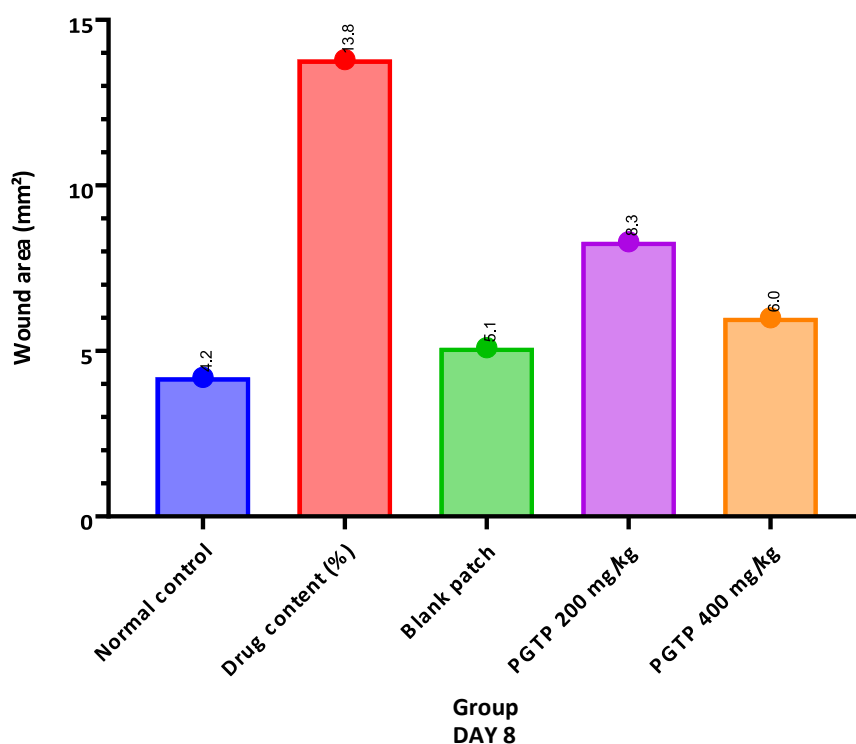
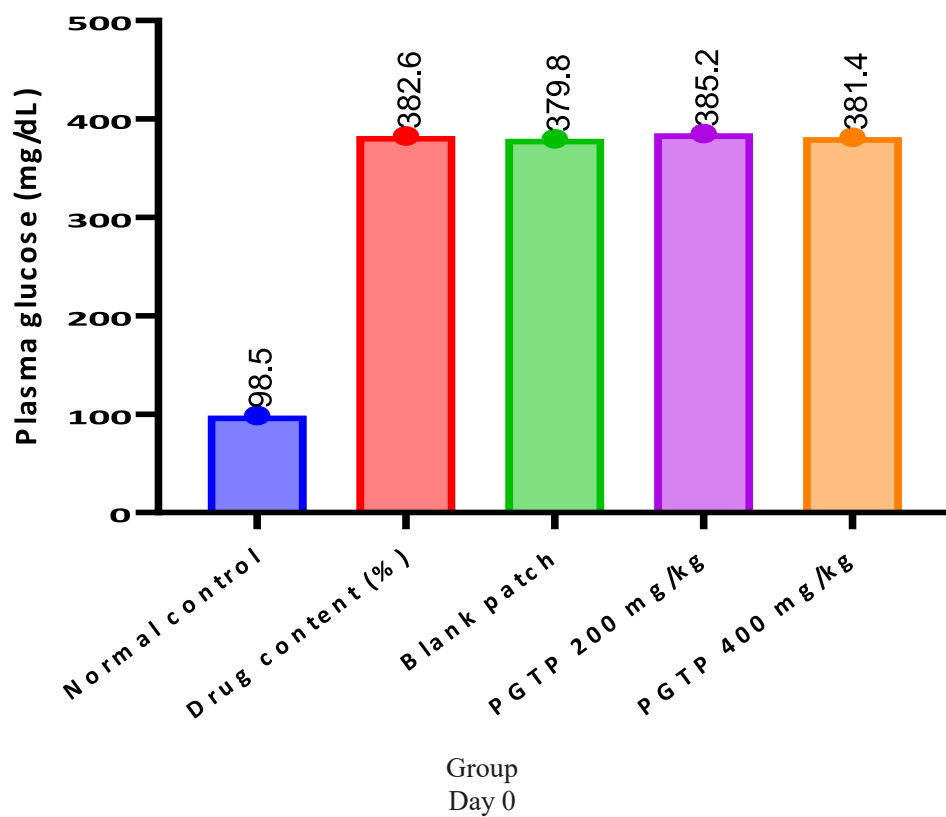


Fig 5: Anti-diabetic and wound-healing effects of PGT

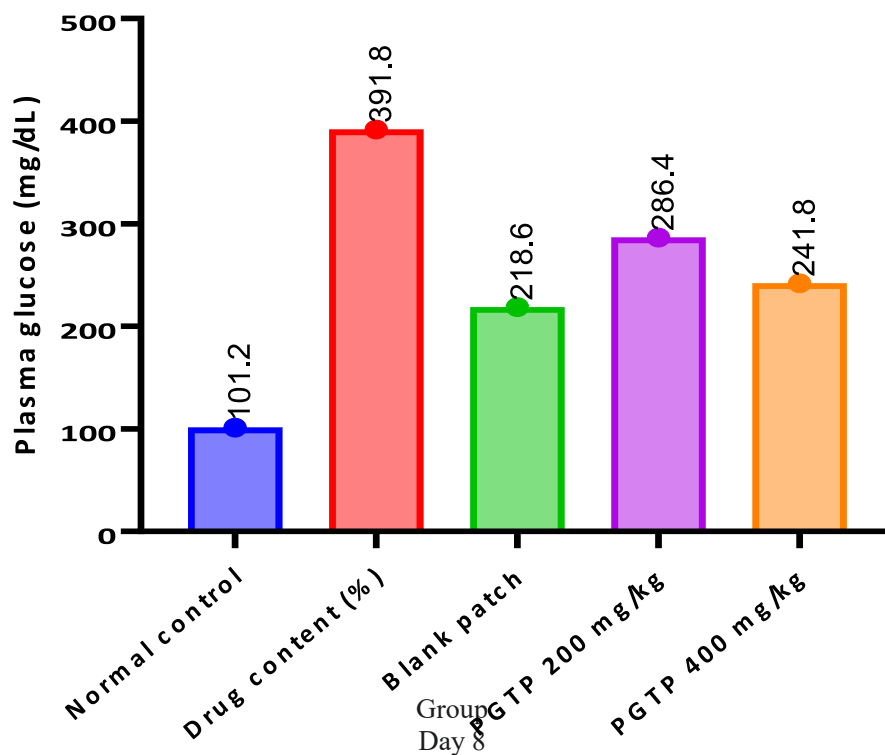
Anti-diabetic and wound-healing effects of PGTP.



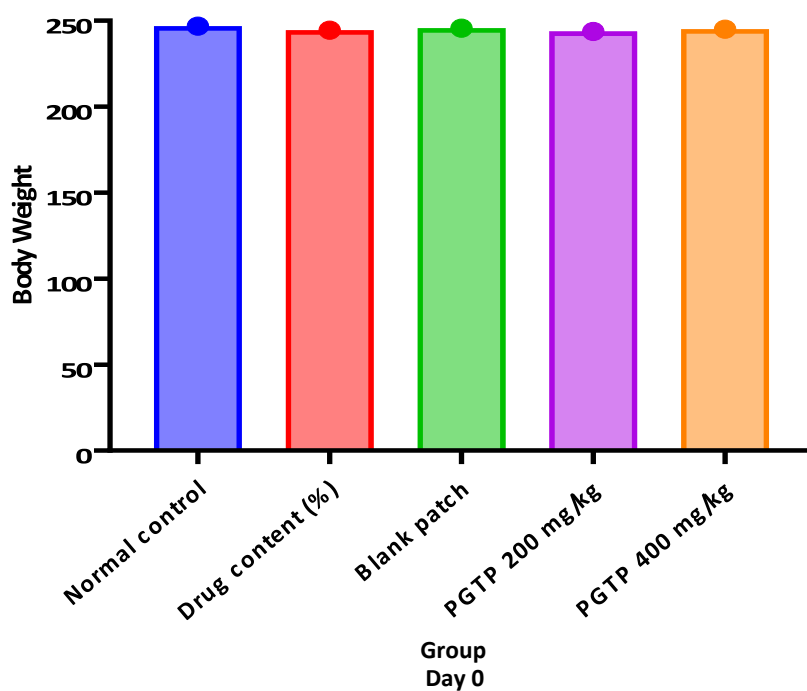
Anti-diabetic and wound-healing effects of PGTP.



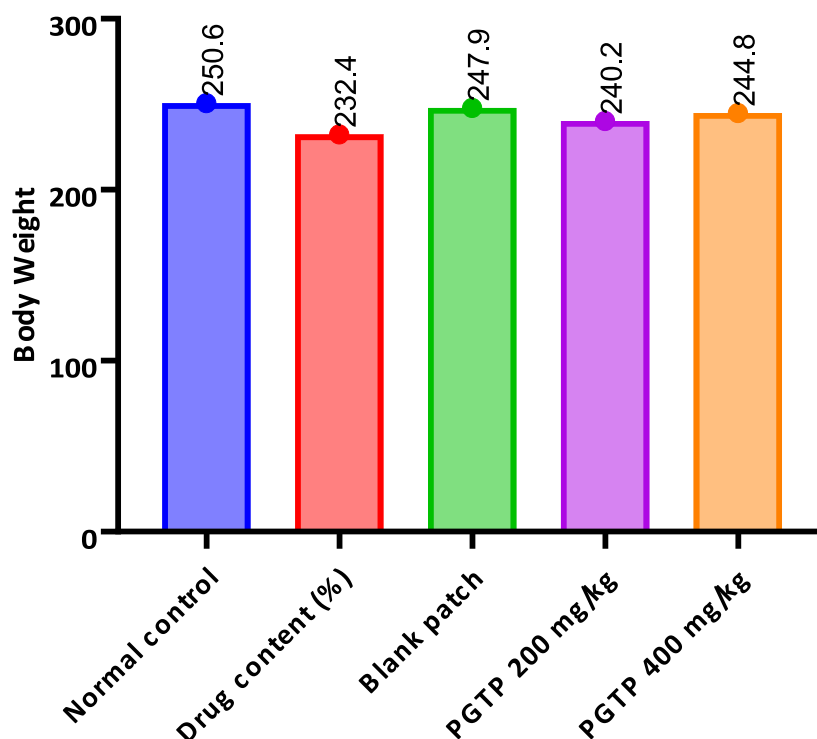
Anti-diabetic and wound-healing effects of PGTP.



Anti-diabetic and wound-healing effects of PGTP.



Anti-diabetic and wound-healing effects of PGTP.



The present study aimed to develop and evaluate a herbal polymeric patch containing an ethanolic extract of *Portulaca grandiflora* as a novel topical approach for wound healing. *Portulaca grandiflora* was selected based on traditional uses in treating wounds, burns, skin disorders, and inflammation, and on reported antioxidant, antibacterial, and antidiabetic activities that may support tissue repair.

Preliminary phytochemical screening of the ethanolic extract revealed alkaloids, flavonoids, phenols, proteins, saponins, tannins, and carbohydrates. By contrast, the aqueous extract tested positive for alkaloids, flavonoids, phenols, saponins, carbohydrates, and tannins but showed no detectable proteins. These results indicate a broader spectrum of phytoconstituents in the ethanolic extract that could contribute to biological activity.

Total flavonoid content of the ethanolic extract was measured by the aluminum chloride colorimetric method using quercetin as the standard. Measured values at the tested concentrations were 71 mg, 88 mg, and 81 mg, with the highest flavonoid content observed at the 200 µg/mL concentration. The presence of substantial flavonoid levels is noteworthy given their known antioxidant and wound repair-related activities.

For formulation development, sodium alginate and sodium carboxymethyl cellulose (Na-CMC) were chosen as film-forming polymers. Glycerol served as a plasticizer, while Tween 80 and PEG-400 were included as excipients to aid homogeneity and handling. Polymer solutions were blended in a 60:40 sodium alginate:Na-CMC ratio, and the ethanolic extract was incorporated to produce a uniform casting solution.

Three formulations (F1–F3) were prepared by varying the amount of ethanolic extract while holding other components constant: F1 (0.5 g extract), F2 (0.75 g), and F3 (1.0 g). This design allowed assessment of how extract concentration affects the physical and functional characteristics of the cast patches, which were evaluated for key physicochemical parameters relevant to topical wound dressings, including physical appearance, thickness, weight uniformity, folding endurance, flatness, moisture content, moisture uptake, surface pH, and water vapor transmission rate. These tests assess film integrity, flexibility, uniformity, and suitability for skin application.

This formulation strategy is supported by literature demonstrating that sodium alginate–Na-CMC films and related polymeric delivery systems can provide appropriate mechanical and barrier properties for wound management. The present work confirms that *P. grandiflora* ethanolic extract, rich in phytoconstituents, can be successfully incorporated into polymeric patches using solvent-casting.

However, because the supplied PDF did not include numeric data for patch evaluation or results from an experimental wound-healing model, no definitive conclusions about the optimized formulation's wound-healing efficacy can be drawn from the available information.

The present study demonstrated that PGTP treatment improved wound healing in STZ-induced diabetic rats. The disease-control group showed delayed wound contraction, increased plasma glucose, and reduced body weight. PGTP treatment reduced wound area and plasma glucose levels while improving body weight maintenance. The effect was more pronounced with **PGTP 400 mg/kg** than with 200 mg/kg, indicating a dose-dependent response. The improved wound healing may be associated with better glycemic control and enhanced tissue repair. Overall, TAPE showed promising **anti-diabetic and wound-healing activity**, with the higher dose producing greater improvement.

DISCUSSION

The egg albumin denaturation test is performed to decide if a drug or chemical can stop or lessen the denaturing of egg albumin, which demonstrates its anti-inflammatory effects, according to a previous study (Dharmadeva S et al., 2018). Antioxidant defenses are made up of different molecules and proteins that work together to counteract and eliminate reactive oxygen species (ROS). The association between ROS and cancer development is complex and varies depending on the situation; however, further research suggests that ROS neutralization may promote tumor growth and spread in some cancer types through several pathways (Hawk, M. A., et al 2018). Devi et al. (2019) examined the initial phytochemical makeup and antidiabetic effects of the extract from *Portulaca grandiflora* Hook. using a rat model with diabetes induced by streptozotocin. The research assessed how the plant extract could affect biochemical alterations related to diabetes in the experimental subjects. Nurcholis et al. (2023) established a link between the levels of polyphenols and the capacity for antioxidant activity, indicating that both flavonoids and phenolic compounds might significantly enhance the antioxidant traits of *P. grandiflora*. These results advocate for additional exploration of the plant as a possible origin of natural antioxidant elements. Trezzini and Zryd et al. revealed that the blooms of *P. grandiflora* house unique betalain pigments and noted the phytochemical variety present in the species. Such outcomes provide a foundation for further study into the biological traits of its floral components. Budiawan et al. (2023) found that wounds treated with the extract exhibited a steadily decreasing size throughout the monitoring period, showcasing the extract's ability to facilitate wound healing. The authors indicated that extracts abundant in flavonoids from *P. grandiflora* may promote healing and warrant additional research for therapeutic uses. Ao (2019) revealed that the results showcased antioxidant activity and pinpointed several chemical components linked to the extracts. The research implied that *P. grandiflora* harbors biologically active substances that might enhance its antioxidant capabilities and promoted expanded pharmacological exploration of the species. Chavan et al. (2025) provided a review of the origins and treatment methods for diabetic foot ulcers. The research clarified that neuropathy, poor circulation, and weakened immune responses hinder wound recovery and raise infection risks. Yadav et al. (2025) analyzed modern treatments and delivery techniques for wound care in diabetes. The findings stated that elevated blood sugar levels, compromised immune responses, infections, oxidative stress, and inadequate angiogenesis slow down the healing process. The authors pointed out that phytochemicals, metal nanoparticles, and polymeric nanocarriers provide promising strategies to enhance drug delivery and facilitate wound healing in diabetic patients. Mus'hib et al. (2024) assessed the wound-healing properties of the n-hexane extract of *Portulaca grandiflora* through both in vitro and in vivo studies. The extract encouraged cell movement and promoted wound closure in scratch tests. In in vivo assessments, the ointment boosted epidermal closure, re-epithelialization, and the formation of granulation tissue. The authors concluded that the phytochemicals found in *P. grandiflora*, particularly terpenoids and steroids, could aid in the healing process.

CONCLUSION

In summary, this research effectively created and assessed a novel herbal polymeric transdermal patch that incorporates the ethanol extract of *Portulaca grandiflora* aimed at treating diabetic wounds. Phytochemical analysis validated a diverse array of bioactive components—like flavonoids, phenolic compounds, and alkaloids—with the highest total flavonoid concentration found at 200 µg/mL, which closely corresponds with strong antioxidant and tissue-repair capabilities. The mixture utilizing sodium alginate alongside sodium carboxymethyl cellulose was shown to be successful in producing a stable patch system suitable for topical application. Additionally, in vivo tests on diabetic rats induced by streptozotocin revealed marked therapeutic benefits. The application of the transdermal patches enhanced the speed of wound healing, reduced blood glucose levels, and improved body weight maintenance when compared to the

control group suffering from the disease. Significantly, the formulation with the higher dosage of 400 mg/kg demonstrated a more effective, dose-dependent response relative to the 200 mg/kg treatment, emphasizing the considerable combined anti-diabetic and wound-healing capability of the delivery method. Although these encouraging results were noted, the transition to clinical application necessitates further thorough exploration. Future studies ought to examine specific mechanistic processes, refine formulation strategies, perform long-term stability assessments, and conduct extensive preclinical and clinical tests to definitively determine the safety, ideal dosage, and therapeutic effectiveness of this herbal transdermal method.

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