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## Wound healing activity of *Ipomoea batatas* tubers (sweet potato)

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### Abstract

**Background:** *Ipomoea batatas* (L.) Lam. from the family Convolvulaceae is the world's sixth largest food crop. The tubers of *Ipomoea batatas* commonly known as sweet potato are consumed as a vegetable globally. The tubers contain high levels of polyphenols such as anthocyanins and phenolic acids and vitamins A, B and C, which impart a potent antioxidant activity that can translate well to show wound healing effects. To check their effects on wound healing, the peels and peel bandage were tested on various injury models in rats in the present study.

**Methods:** The methanolic extracts of the peels and peel bandage of *Ipomoea batatas* tubers (sweet potato) were screened for wound healing by excision and incision wound models on Wistar rats. Three types of gel formulations were prepared, viz., gel containing 3.0% (w/w) peel extract, gel containing 6.0% (w/w) peel extract and gel containing 10% (w/w) peel extract. Betadine (5% w/w povidone iodine cream) was used as a reference standard. In the incision wound model, Tensile strength of the skin was measured. Epithelization time, wound contraction, hydroxyproline content of the scab, and ascorbic acid and malondialdehyde content of the plasma were determined in the excision wound model.

**Results:** In the incision wound model, high tensile strength of the wounded skin was observed in animals treated with the peel extract gels and the peel bandage when compared with wounded control animals. The increase in tensile strength indicates the promotion of collagen fibers and that the disrupted wound surfaces are being firmly knit by collagen. In the excision wound model, significant wound closure was observed on the 4<sup>th</sup> day in rats treated with all three gel formulations when compared with the wounded control rats. A significant increase in

hydroxyproline and ascorbic acid content in the gel-treated animals and a significant decrease in malondialdehyde content in the animals treated with gel as well as peel bandage was observed when compared with the wounded control animals.

**Conclusion:** It may be concluded that the peels of *Ipomoea batatas* tubers possess a potent wound healing activity, which may be due to an underlying antioxidant mechanism.

**Key Words:** Sweet potato peels, excision wound, incision wound, wound healing

## BACKGROUND

The skin is the largest organ of the body that acts as a barrier against external agents. The loss of skin tissue integrity can cause lesions or illnesses that could be fatal [1]. Wounds are inescapable events of life; wounds may arise due to physical, chemical or microbial agents and wound healing has been one of the earliest medical problems.

Wound healing is the process of repair that follows injury to the skin and other soft tissues. Following injury, an inflammatory response occurs and the cells below the dermis begin to increase collagen production [2]. Later, the epithelial tissue is regenerated. Wound healing consists of an orderly progression of events that re-establish the integrity of the damaged tissue [1]. There are three main phases of wound healing viz., inflammatory, proliferative and remodeling phase. The inflammatory phase begins immediately after injury with vasoconstriction that favors and releases inflammatory mediators. The proliferative phase is characterized by granulation tissue formation mainly by fibroblasts and angiogenesis. The remodeling phase is characterized by reformulation and improvement in the components of the collagen fiber that increases the tensile strength.

*Ipomoea batatas* (L.) Lam. from the family Convolvulaceae is the world's sixth largest food crop which is widely grown in tropical, subtropical and warm temperate regions [3]. The tuber of *Ipomoea batatas* is commonly known as sweet potato. It is also called kamote, lapni, yams and tugi in various parts of the world. The boiled tubers are consumed as a vegetable globally. The tuber is often long and tapered and the skin may be red, purple, or brown and white in color. The flesh may be white, yellow, orange or purple. The *I. batatas* plant has been used extensively in traditional medicines for various ailments [4, 5].

Current methods used to treat wounds include debridement, irrigation, use of antiseptics, antibiotic and corticosteroid therapy, and tissue grafts [6]. However, these methods are associated with unwanted side effects such as potential for bacterial resistance, bleeding, tissue damage, contact dermatitis and delay in wound healing.

Another interesting practice to treat a wound is the use of potato peel bandage as an occlusive dressing [7]. This serves the dual purpose of protecting the wound from external damage as well as providing a therapeutic benefit due to the presence of wound healing constituents. There has been no research regarding the usage of sweet potato peels for treatment of wounds. Thus, research on the therapeutic use of sweet potato peels for wound treatment will add to the development of newer wound healing agents.

The tubers and skin of *Ipomoea batatas* contain high levels of polyphenols, such as anthocyanins and phenolic acids and are also a good source of vitamins A, B and C, iron, calcium and phosphorus [8]. A potent antioxidant activity due to the presence of antioxidants such as beta carotene, anthocyanins, caffeoylcaucic acid and caffeoylquinic acid derivatives can translate well to show wound healing effects [9, 10]. Hence, testing of the wound healing potential of the peels of sweet potato is proposed.

The present research was undertaken to evaluate the wound healing activity of the peels of *Ipomoea batatas* tubers (sweet potato).

## **MATERIALS AND METHODS:**

### **Plant material**

Fresh tubers of sweet potato were collected from Colaba market, Colaba, Mumbai and authenticated at the Blatter herbarium, St. Xavier College, Mumbai (Accession no. 47280). Whole tubers were washed with distilled water to remove the exudates from their surfaces.

### **Drugs and chemicals**

Thiobarbituric acid (TBA), trichloroacetic acid (TCA) and L-hydroxyproline, were obtained from Himedia Laboratories, Mumbai, India. Ascorbic acid and 2,4-dinitrophenyl hydrazine were obtained from Merck Ltd., Mumbai. All other chemicals were obtained from local sources and were of analytical grade.

### **Extraction**

Peel Extract (PE): The peels of sweet potato tubers were removed, dried at 60°C and extracted with methanol.

Peel Bandage (PB): For making the bandage, tubers were boiled and peels were separated. Approximately 1 g of wet peels was used. With the aid of cotton and gauze, bandages of the peels were prepared and applied as such.

### **Preparation of gels [11, 12]**

Carbopol 974P NF (0.25 g) was dispersed in 22 ml of distilled water and mixed by stirring continuously in a magnetic stirrer at 800 rpm for 1 h. Glycerol (1.25 g) was added to the mixture under continuous stirring. The mixture was neutralized by drop-wise addition of 50 % triethanolamine. Mixing was continued until a transparent gel was formed. Three types of gel formulations were prepared viz., gel containing 3.0 % (w/w) peel extract, gel containing 6.0 % (w/w) peel extract and gel containing 10 % (w/w) peel extract.

### **Experimental animals**

Wistar albino rats (150-200 g) of either sex were used. They were housed in clean polypropylene cages under standard conditions of humidity (50 ± 5 %), temperature (25±2°C) and light (12 h light/12 h dark cycle) and fed with a standard diet (Amrut laboratory animal feed, Pune, India) and water *ad libitum*. All animals were handled with humane care. Experimental protocols were reviewed and approved by the Institutional Animal Ethics Committee (Animal House Registration No.25/1999/CPCSEA) and conform to the Indian National Science Academy Guidelines for the Use and Care of Experimental Animals in Research.

**Acute toxicity study (ALD50)**

Acute toxicity studies were carried out on Wistar rats by the topical route at dose levels up to 2000 mg/kg of the peel extract of *Ipomoea batatas* tubers, as per the OECD- guidelines No.402.

**Wound healing activity**

Adult Wistar albino rats of either sex weighing 180-200 g were used for the study. The effects of the peel extract and peel bandage were evaluated on excision and incision wound models in rats. Betadine (5% w/w povidone iodine cream) was used as a standard drug for comparing the wound healing potential of the extract in different animal models.

**Excision wound model [13]**

Animals, after acclimatization (6–7 days) in the animal quarters, were randomly divided into six groups of six animals each and treated in the following way:

Group I – Wounded control (untreated) group

Group II – Peel bandage group

Group III – Test treatment group (3% peel extract gel)

Group IV – Test treatment group (6% peel extract gel)

Group V– Test treatment group (10% peel extract gel)

Group VI– Standard treatment group (Betadine 5% w/w povidone iodine cream)

Animals were anaesthetized by open mask method using ether before wound creation. The particular skin area was shaved 1 day prior to the experiment. A full thickness of the excision wound of circular area (approx. 500 mm<sup>2</sup>) and 2 mm depth was made on the shaved back of the rats. The wound was left undressed to the open environment. The peel extract gel and peel bandage and the standard Betadine (5% w/w povidone iodine cream) were topically applied twice a day to the respective groups (Groups II to VI) till the wound was completely healed. Wound closure was studied by tracing the raw wound using transparent paper and a permanent marker on every 4<sup>th</sup> day for 16 days. Wound area was measured by retracing the wound on a millimeter scale graph paper. The period of epithelization was calculated as the number of days required for falling off of the dead tissue remnants without any residual raw wound. On the 10<sup>th</sup> day, the scab was removed and used for hydroxyproline estimation and the plasma was separated from blood for malondialdehyde (MDA) and ascorbic acid assays.

**Collection of granulation tissue:**

Granulation tissues from the wounded control and treated rats were collected, washed well in cold saline (0.9% w/v NaCl) and lyophilized for L- Hydroxyproline estimation [14].

**L-Hydroxyproline estimation:**

On the 10<sup>th</sup> day, granulation tissue was isolated from each group of rats for estimation of the hydroxyproline content. Hydroxyproline was measured using the method of Bergman & Loxley as follows [15].

Preparation of standard curve:

- Stock solution of 100 µg/ml of hydroxyproline was prepared in 0.001M aqueous hydrochloric acid.

- Appropriate amounts of aliquots of the stock solution of hydroxyproline were used to get a concentration range from 10-100 µg/ml (10, 20, 40, 60, 80, and 100 µg/ml).
- To 2 ml of the above solutions, 1 ml of the oxidant solution [1ml of 7 % w/v aqueous Chloramine T solution and 4ml of acetate citrate buffer (pH-6)] was added and the solutions were mixed and allowed to stand for 4±1 minutes at a room temperature (25-30<sup>0</sup>C).
- The color was developed by adding 13 ml of the Ehrlich reagent to each solution. The solutions were mixed well, heated for 25 minutes at 60<sup>0</sup>C ± 0.2<sup>0</sup>C, cooled for 2 to 3 minutes in running tap water and then transferred to 50 ml volumetric flasks and diluted up to the mark with isopropanol.
- The absorbance of the color was measured at 558 nm against reagent blank.

Extraction of hydroxyproline from the scab:

#### A. Preparation of hydrolysate

The scab (about 250 mg) removed from the excision wound of each animal was dried in an oven at 60<sup>0</sup>C for 24 h and 100 mg was placed in a sealed tube containing 2 ml of 6 N hydrochloric acid. The scab was hydrolyzed by heating the sealed tube at 110<sup>0</sup>C for 4 h; the hydrolysate, thus obtained was neutralized with 10 N sodium hydroxide.

#### B. Estimation of hydroxyproline in the scab

The above hydrolysate (2 ml) was transferred to a 50 ml test tube and the color was developed following the procedure as described earlier. The concentration of hydroxyproline in the scabs was determined by extrapolating from the standard curve and was expressed as µg of L-hydroxyproline /100 mg protein.

### ***Collection of blood***

Blood samples were collected from the retro-orbital plexus of the eye in sterile eppendorfs rinsed with EDTA. Plasma was separated for malondialdehyde and ascorbic acid estimation [14].

### ***Malondialdehyde (MDA) estimation:***

Malondialdehyde was measured using the method of Yagi et al [16]. To 0.1 ml of the plasma, 0.9 ml of 10% TCA and 2 ml of 0.67% TBA reagent were added and kept in boiling water bath for 20 min. The tubes were cooled after centrifugation and the absorbance of the supernatant was read at 532 nm. The MDA concentration was calculated from the standard graph. The results were expressed as nmol of MDA/mg protein using molar extinction coefficient of the chromophore ( $1.56 \times 10^5$ /M/cm) and 1,1,3,3-tetraethoxypropane as standard

### ***Ascorbic acid estimation:***

Ascorbic acid was measured using the method of Omayer et al [17]. To 0.5 ml of plasma, 0.5 ml of ice cold 10% TCA was added, mixed thoroughly and centrifuged for 20 min at 3500 g. Supernatant (0.5 ml) was mixed well with 0.1ml of DTC reagent (2,4-dinitrophenyl hydrazine-thiourea-CuSO<sub>4</sub> reagent) and incubated at 37<sup>0</sup>C for 3h. Then, 0.75ml of ice cold 65% H<sub>2</sub>SO<sub>4</sub> was added, the reaction mixture was allowed to stand at room temperature for 30 min and the yellow color developed was read at 520nm. Standard curve was prepared by using various aliquots from the ascorbic acid stock solution. The unknown ascorbic acid concentration was obtained by extrapolation from the standard curve. The results were expressed as g/dL of ascorbic acid.

**Incision wound model [18]**

Animals, after acclimatization (6–7 days) in the animal quarters, were randomly divided into five groups of six animals each and treated in the following way:

Group I – Wounded control (untreated) group

Group II – Peel bandage group

Group III – Test treatment group (3% peel extract gel)

Group IV – Test treatment group (6% peel extract gel)

Group V – Standard treatment group (Betadine 5% w/w povidone iodine cream)

Animals were anaesthetized by open mask method with anesthetic ether before wound creation. The particular skin area was shaved 1 day prior to the experiment. Incision wounds of about 6 cm in length and 2mm in depth were made with sterile scalpel on the shaved back of the rats. The parted skin was held together and sutured with surgical thread at 1 cm intervals using a curved needle (no.11). The continuous thread on both wound edges was tightened for good closure of the wounds. The wounds of animals in the respective groups (Groups II to V) were treated with the topical applications of peel extract gel and peel bandage and standard betadine for a period of 10 days. When wounds were healed thoroughly, the sutures were removed on the 8<sup>th</sup> post-wounding day. Animals were humanely sacrificed using ether on the 10<sup>th</sup> day and the tensile strength (weight in grams required to break open the wound/skin) was measured immediately by a Tensiometer.

**Tensiometer: [19]**

The tensiometer consists of a 6 x 12 inch wooden board with one arm of 4 inch length, fixed on each side of the possible longest distance of the board. The board was placed at the edge of a table. A pulley with a bearing was mounted on the top of one arm. An alligator clamp with 1 cm width was tied on the tip of the other arm by a fishing line in such a way that the clamp could reach the middle of the board. Another alligator clamp was tied on a longer fishing line with a weighing pan on the other end.

**Determination of tensile strength: [19]**

Sutures were removed on the 8<sup>th</sup> day after wounding and tensile strength was measured on the 10<sup>th</sup> day. The peel extract gels, peel bandage and the standard were applied topically throughout the period, once daily for 9 days. On the 10<sup>th</sup> day, the rats were again anaesthetized and each rat was placed on the middle of the board. The clamps were then carefully attached to the skin on the opposite sides of the wound at a distance of 0.5 cm from the wound. The longer pieces of the fishing line were placed on the pulley and finally on to the weighing pan and weights were added until the wound began to open. The amount of weight required to break the wound is considered as a direct measure of the tensile strength of the wound. The tensile strength of the wounds of all the treatment group animals was compared with that of the wounded control group animals.

**Statistical analysis:**

The results of wound healing activity were expressed as mean  $\pm$  SEM. Results were statistically analyzed using one-way ANOVA, followed by the Tukey–Kramer post test for individual comparisons.  $P < 0.05$  were considered to be significant.

## RESULTS:

### Excision wound model

#### Wound contraction

Wound contraction is an important parameter used to assess wound healing. The percentage wound contraction was determined using the following formula [20]:

$$\text{Percent wound contraction} = \frac{\text{Healed area}}{\text{Total wound area}} \times 100$$

Wound area was measured by tracing the wound margin using a transparent paper at a 4-day interval and the healed area was calculated by subtracting from the original wound area [20]. On day 4, the wound contractions of all treated groups were found to be significantly higher [standard ( $P < 0.001$ ), 10% peel extract gel ( $P < 0.001$ ), 6% peel extract gel ( $P < 0.01$ ), 3% peel extract gel ( $P < 0.01$ ), and peel bandage ( $P < 0.05$ )] than the contraction in the wounded control group. Also, on the 8<sup>th</sup>, 12<sup>th</sup> and 16<sup>th</sup> days, the wound contractions of all treated groups were found to be significantly higher than that in the wounded control group.

On the 18<sup>th</sup> day, the wound treated with 10% peel extract gel had completely healed while the wound treated with the standard (5% w/w povidone iodine) had also reached the complete healing stage. On the 19<sup>th</sup> day, the standard treated group healed 100%, 6% peel extract gel treated group healed 95.32%, 3% peel extract gel treated group healed 90.78% and peel bandage treated group healed 88.07%. It was also observed that the epithelization period of the treatment and standard groups was less in comparison with the wounded control group (Table 1).

**Table 1.** Effect of peel extract gel and peel bandage of *Ipomoea batatas* tubers on wound contraction and epithelization in the excision wound model in Wistar rats

Groups/ Doses	% Wound Contraction				
	4 <sup>th</sup> day	8 <sup>th</sup> day	12 <sup>th</sup> day	16 <sup>th</sup> day	Period of Epithelization (Days)
Wounded Control	5.65 $\pm$ 1.43	25.02 $\pm$ 0.13	51.92 $\pm$ 0.10	78.02 $\pm$ 0.20	28
Peel Bandage (1gm)	11.48 $\pm$ 1.43 <sup>a</sup>	37.71 $\pm$ 0.21 <sup>a</sup>	63.57 $\pm$ 2.5 <sup>a</sup>	88.07 $\pm$ 0.82 <sup>a</sup>	25
Peel extract gel (3% w/w)	12.76 $\pm$ 0.25 <sup>b</sup>	36.62 $\pm$ 0.31 <sup>b</sup>	68.61 $\pm$ 2.52 <sup>b</sup>	90.78 $\pm$ 0.36 <sup>b</sup>	23
Peel extract gel (6% w/w)	13.29 $\pm$ 0.44 <sup>b</sup>	39.51 $\pm$ 0.21 <sup>b</sup>	73.35 $\pm$ 0.49 <sup>b</sup>	95.32 $\pm$ 0.25 <sup>c</sup>	21
Peel extract gel (10% w/w)	14.39 $\pm$ 1.04 <sup>c</sup>	50.91 $\pm$ 0.21 <sup>c</sup>	79.82 $\pm$ 0.51 <sup>c</sup>	97.04 $\pm$ 0.12 <sup>c</sup>	18
Povidone iodine cream (5% w/w)	13.84 $\pm$ 1.37 <sup>b</sup>	44.44 $\pm$ 0.11 <sup>b</sup>	78.02 $\pm$ 2.6 <sup>c</sup>	96.35 $\pm$ 0.15 <sup>c</sup>	19

Values are Mean  $\pm$  SEM from 6 animals in each group.

<sup>a</sup> P value < 0.05 when experimental groups compared with wounded control group.

<sup>b</sup> P value < 0.01 when experimental groups compared with wounded control group.

<sup>c</sup> P value < 0.001 when experimental groups compared with wounded control group.

## Biochemical parameters

### Hydroxyproline

In our study, the hydroxyproline content was found to be significantly increased in standard ( $P < 0.001$ ), 10% peel extract gel ( $P < 0.001$ ), 6% peel extract gel ( $P < 0.01$ ), and 3% peel extract gel ( $P < 0.05$ ) when compared with the wounded control group. However, the peel bandage group did not show significant increase in hydroxyproline content when compared with the wounded control group (Table 2). An increase in hydroxyproline content indicates increased collagen synthesis, thus, enhanced wound healing.

**Table 2.** Effect of peel extract gel and peel bandage of *Ipomoea batatas* tubers on L-hydroxy proline, malondialdehyde and ascorbic acid content in the excision wound model in Wistar rats

Groups	L-Hydroxy Proline (mg/g tissue)	Malondialdehyde (Lipid Peroxidation) nmoles of MDA/mg protein	Ascorbic acid (gm/dl )
Wounded control group	9.221 $\pm$ 0.246	0.806 $\pm$ 0.048	2.590 $\pm$ 0.252
Peel bandage group	11.036 $\pm$ 0.379	0.606 $\pm$ 0.029 <sup>b</sup>	4.118 $\pm$ 0.153
Peel extract gel (3% w/w)	12.847 $\pm$ 0.756 <sup>a</sup>	0.595 $\pm$ 0.049 <sup>b</sup>	4.377 $\pm$ 0.259 <sup>a</sup>
Peel extract gel (6% w/w)	13.15 $\pm$ 0.724 <sup>b</sup>	0.452 $\pm$ 0.004 <sup>c</sup>	4.618 $\pm$ 0.396 <sup>b</sup>
Peel extract gel (10% w/w)	14.633 $\pm$ 0.920 <sup>c</sup>	0.35 $\pm$ 0.013 <sup>c</sup>	5.886 $\pm$ 0.322 <sup>c</sup>
Povidone iodine cream (5% w/w)	14.47 $\pm$ 0.915 <sup>c</sup>	0.404 $\pm$ 0.025 <sup>c</sup>	5.736 $\pm$ 0.441 <sup>c</sup>

Values are Mean  $\pm$  SEM from 6 animals in each group.

<sup>a</sup> P value < 0.05 when experimental groups compared with wounded control group.

<sup>b</sup> P value < 0.01 when experimental groups compared with wounded control group.

<sup>c</sup> P value < 0.001 when experimental groups compared with wounded control group.



**Malondialdehyde**

The malondialdehyde content was found to be significantly decreased in standard ( $P < 0.001$ ), 10% peel extract gel ( $P < 0.001$ ), 6% peel extract gel ( $P < 0.001$ ), 3% peel extract gel ( $P < 0.01$ ) and peel bandage ( $P < 0.01$ ) groups when compared with the wounded control group (Table 2), thus, demonstrating an anti-lipid peroxidative effect of the *I. batatas* extract, augmenting wound healing.

**Ascorbic acid**

In our study, the ascorbic acid content was found to be significantly increased in standard ( $P < 0.001$ ), 10% peel extract gel ( $P < 0.001$ ), 6% peel extract gel ( $P < 0.01$ ), and 3% peel extract gel ( $P < 0.05$ ) groups when compared with the wounded control group. However, the peel bandage group did not show a significant increase in ascorbic acid content when compared with the wounded control group (Table 2). An increased ascorbic acid content in the peel extract gel-treated groups is reflective of a good antioxidant status and thus, improved wound healing.

**Incision wound model****Tensile strength**

In our study, the tensile strength of skin was found to be significantly increased in standard ( $P < 0.001$ ), 6% peel extract gel ( $P < 0.001$ ), 3% peel extract gel ( $P < 0.01$ ) and peel bandage ( $P < 0.05$ ) groups when compared with the wounded control group of animals (Table 3). The increase in tensile strength of treated wounds may be due to an increase in collagen concentration and stabilization of the fibers facilitating wound healing.

**Table 3.** Effect of peel extract gel and peel bandage of *Ipomoea batatas* tubers on tensile strength in the incision wound model in Wistar rats.

Groups	Tensile strength (g)
Wounded control group	310 ±2.887
Peel bandage group	355 ±5.701 <sup>a</sup>
Peel extract gel (3% w/w)	379 ±8.276 <sup>b</sup>
Peel extract gel (6% w/w )	443 ±10.440 <sup>c</sup>
Povidone iodine cream (5% w/w)	430 ±14.72 <sup>c</sup>

Values are Mean ± SEM from 6 animals in each group.

<sup>a</sup> P value < 0.05 when experimental groups compared with wounded control group.

<sup>b</sup> P value < 0.01 when experimental groups compared with wounded control group.

<sup>c</sup> P value < 0.001 when experimental groups compared with wounded control group.

**DISCUSSION**

The wound healing process consists of different phases such as granulation, collagenation, collagen maturation and scar maturation which are concurrent but independent of each other

[20]. Hence, in this study two different models were used to assess the effect of peels of *Ipomoea batatas* tubers (sweet potato) on various phases. The results of the present study showed that the peels of sweet potato possessed a definite pro-healing action.

Wound contraction, the process of shrinkage of area of the wound depends on the reparative abilities of the tissue, type and extent of the damage and general state of the health of the tissue [21]. In the excision wound model, the extract of the peels and peel bandage of the *Ipomoea batatas* tubers showed significant increase in percentage closure of the wounds by enhanced epithelization. This enhanced epithelization may be due to the antioxidant effect of the peels, which augments collagen synthesis.

Collagen, the major protein of the extracellular matrix, is the component that ultimately liberates free hydroxyproline and its peptides [22]. The measurement of hydroxyproline can be used as an index for collagen turnover. Increase in hydroxyproline content indicates increased collagen synthesis which in turn leads to enhanced wound healing. The hydroxyproline content in wounds treated with hydrogel containing peel extracts and peel bandage was found to be higher than that in the wounded control animals.

An elevation in the levels of end products of lipid peroxidation in wounded control rats was observed. The increase in MDA levels suggests enhanced peroxidation and failure of the antioxidant defense mechanisms to prevent the formation of excessive free radicals [23]. Treatment with the peel extract gel and peel bandage significantly reversed these changes. Hence, it is likely that the mechanism of wound healing of the peels of *Ipomoea batatas* tubers is due to its ability to scavenge free radicals.

Ascorbic acid is a known antioxidant that possesses potent free radical scavenging activity and inhibits lipid peroxidation [9]. In the present study, the ascorbic acid level was found to be higher in the test treatment groups than the wounded control group of rats, and hence a decline in lipid peroxidation was observed, indicating an antioxidant effect. Thus, free radical scavenging effect of the peels and peel extracts of *Ipomoea batatas* (in a dose related manner) might be one of the most important components of wound healing.

The tensile strength of a wound is determined by the rate of collagen synthesis and more so, by the maturation process where there is a covalent binding of collagen fibrils through inter and intra molecular cross linking [24]. In the incision wound study, there was a significant increase in tensile strength of the 10-day old wound due to treatment with the peel extract gel, peel bandage and the standard drug. The tensile strength of the standard drug (Povidone iodine cream (5% w/w)) and the 6% peel extract gel treated groups was comparable but much greater than that of the peel bandage group. The increase in tensile strength of treated wounds may be due to an increase in collagen concentration and stabilization of the fibers facilitating wound healing. This increase in collagen synthesis may be due to the antioxidant effect of the peels, which enhances wound healing

Phytochemical investigations of the peel extract showed the presence of high levels of polyphenols (anthocyanins and phenolic acids) and sesquiterpenoids (6-myoporol, 4-hydroxydehydromyoporone and ipomeamarone) [25, 26]. Anthocyanins, phenolic acids (caffeoylquinic acid derivatives like chlorogenic, dicaffeoylquinic, and tricaffeoylquinic acids) and  $\beta$ -carotene have been documented to possess potent antioxidant and free radical scavenging

effect, which is believed to be one of the most important components of wound healing [25, 27]. Thus, the enhanced wound healing may be due to this free radical scavenging effect. The wound healing property of *Ipomoea batatas* may probably be due to the presence of the potent antioxidants present therein [6].

### CONCLUSION:

In conclusion, our study demonstrates that the peels of *Ipomoea batatas* tubers possess a potent wound healing effect, which appears to be related to the free radical scavenging activity of the phytoconstituents, and their ability to inhibit lipid peroxidative processes. The present study, thus, aims to highlight the health benefits of sweet potato, establish it as a potent “functional food” and promote its use as a vegetable to enrich people’s diets. Also if proved a putative therapeutic aide, the peels of *Ipomoea batatas* tubers could well serve as one of the candidates for the wound healing process.

### Competing interests:

The authors declare that they have no competing interests.

### Authors’ contributions

Vandana Panda, conceived, designed, co-ordinated and supervised the study and the writing of the manuscript. Madhav Sonkambale, initiated the study, carried out the experimental, performed statistical analysis and drafted the manuscript. Swati Patil, gave valuable inputs on the extraction process and other pharmacognostic aspects of this study.

All authors read and approved the final manuscript.

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