Contents lists available at ScienceDirect

Asian Pacific Journal of Tropical Disease

journal homepage: www.elsevier.com/locate/apjtd

Document heading doi: 10.1016/S2222-1808(14)60414-X

Wound healing activity of standardized extract of *Curculigo orchioides* in streptozotocin-induced diabetic mice

Anurag Singh[1], Surabhi Bajpai[1], Nisha Singh[1], Vinod Kumar[1], Jalaj Kumar Gour[1], Pramod Kumar Singh[2], Rakesh Kumar Singh[1*]

[1]*Department of Biochemistry, Faculty of Science, Banaras Hindu University, Varanasi, India*

[2]*Department of Botany, Udai Pratap Autonomous College, Varanasi, India*

PEER REVIEW

Peer reviewer

Prof. Shridhar Dwivedi, MD, PhD (Cardiology), FRCP (London) FAMS, FIACS (Canada) PG Dip HPA (Leeds), Dean/ Principal, Professor of Medicine/ Preventive Cardiology, Hamdard Institute of Medical Sciences and Research, Jamia Hamdard (Hamdard University), New Delhi-110062, India.
E-mail: shridhar.dwivedi@gmail.com

Comments

The is an interesting study in which the results suggested that *C. orchioides* promoted the faster wound healing in the case of diabetic persons due to present of flavonoides, tannin, *etc*.
Details on Page S52

ABSTRACT

Objective: To calculate the effect of methanolic extract of *Curculigo orchioides* (*C. orchioides*) on rate of wound contraction and estimation of various biochemical parameters such as superoxide dismutase, lipid peroxidation and nitric oxide levels in the granulation tissue of diabetic and non-diabetic mice.

Methods: The methanolic extract of *C. orchioides* with the concentration of 200 mg/kg and 400 mg/kg body weight was induced through intraperitoneal injections in diabetic and non-diabetic mice. The results were compared with control and metformin induced diabetic and non-diabetic mice.

Results: The results showed that root tubers of *C. orchioides* were a potent source of antioxidative phenolic compounds that counteract with reactive oxygen species responsible for delayed wound healing. The root tubers of *C. orchioides* significantly increased the level of superoxide dismutase, nitric oxide and decreased lipid peroxidation in granuloma tissue of diabetic mice.

Conclusions: The extract of root tubers of *C. orchioides* increases the rate of angiogenesis and improves antioxidant enzymes status that eventually leads to faster wound healing in diabetic condition. However, further studies are needed to explore the molecules present in *C. orchioides* that lead to faster wound healing.

KEYWORDS

Antidiabetic, Delayed wound healing, *Curculigo orchioides*, Antioxidant, Natural product, SOD, LPO, NO

1. Introduction

Plants constitute the richest source of natural antioxidants to counteract reactive oxygen species (ROS). ROS are continuously generated inside the human body as a result of contacting with excess of exogenous chemicals in our ambient environment and/or due to a number of endogenous metabolic processes involving redox enzymes[1]. ROS are thought to be harmful to human health and to trigger many diseases arteriosclerosis, inflammatory disorders, cancer, coronary disease and diabetes. Hence natural antioxidants due to their radical scavenging ability are considered as possible protection against many chronic diseases as well as lipid peroxidation (LPO)[2,3]. Many medicinal plants are found useful in treating wounds such as *Alternanthera sessilis*, *Morinda citrifolia*, *Lycopodium serratum*, *Sesamum indicum*, *Catharanthus roseus*, *Cecropia peltata*, *Euphorbia hirta*, *Ginkgo biloba*, *Clerodendrum serratum*, *Pterocarpus santalinus*, *Lawsonia alba*, *Napoleona imperialis*, *Kaempferia galangal*, *Radix paeoniae*, *Prosopis cineraria* and *Trigonella foenum-graecum* .

This study explores the wound healing activity of *Curculigo orchioides* Gaertn. (Hypoxidaceae) (*C. orchioides*) with their recent advancement in treating

*Corresponding author: Dr. Rakesh Kumar Singh, Department of Biochemistry, Faculty of Science, BHU, Varanasi, India.
Tel: 09415776906, 09415615185
E-mail: singhanurag21@gmail.com, rakeshbhu@yahoo.com

Foundation Project: Supported by Council of Scientific and Industrial Research (CSIR), Human Resource Development Group, Pusa, New Delhi, for Surabhi Bajpai (Senior Research Fellowship, File No.9/13(295)/2010-EMR-1).

Article history:
Received 9 Nov 2013
Received in revised form 17 Nov, 2nd revised form 29 Nov, 3rd revised form 3 Dec 2013
Accepted 29 Dec 2013
Available online 28 Jan 2014

chronic wounds in diabetic condition. Diabetes mellitus is one of the major contributors to chronic wound healing problems. When diabetic patients develop an ulcer, they are exposed to high risk for major complications including infection and amputation. It has been suggested that diabetes impairs wound healing through disruption of local cytokine production, notably platelet derived growth factor, tumor necrosis factor α, interleukin 1β, and vascular endothelial growth factor, reduced biosynthesis or accelerated degradation of newly synthesized collagen[4-6]. Wound healing process involves several steps, including contraction, granulation, epithelization and formation of collagen[7]. This is mainly achieved by synthesis of new connective tissue matrix. Collagen is a major protein of the extracellular matrix and is the major component that ultimately contributes to wound strength. Tannins promotes the wound healing through several cellular mechanisms, chelating of the free radicals and reactive species of oxygen, promoting contraction of the wound and increasing the formation of capillary vessels and fibroblasts.

C. orchioides also known as black musali, is a tiny herbal plants widely distributed in China, Malaya, Japan, Australia and also in subtropical Himalayas region of India. *C. orchioides* included in the IUCN category of "lower risk near threatened" medicinal plants, so it requires *ex-situ* and *in-situ* conservation. This plant has been used to treat a wide assortment of diseases such as asthma, piles, jaundice, diabetes, leucorrhoea and urinary disorder. Root tuber is the main essential part of black musali, which is an essential component of several Ayurvedic formulations such as vidaryadighrta, vidaryadi lehya and musalyadi churan[8].

Phenolic compounds such as phenolic acids, flavonoids and tannins are important plant metabolites that play a significant role in the diabetic wound healing. Tannins act as free radical scavengers, triterpenoids and flavonoids that promote wound healing due to their astringent and antimicrobial property, and saponins due to their antioxidant and antimicrobial activity which appear to be responsible for wound contraction and elevated rate of re-epithelialization. Flavonoids also possess potent antioxidant and free radical-scavenging effect, enhancing the level of antioxidant enzymes in granuloma tissue[9].

Wang and Li have isolated phenolic glycosides, crassifoside G and isocrassifoside G from the root stock of *C. orchioides*[10]. The root tubers are also reported to contain antioxidative phenols and certain phenolic glycosides such as orcinol glucoside (1), orcinol-1-O-beta-D-glucopyranosyl-(1-->6)-beta-D-glucopyranoside (2), orcinol-1-O-beta-D-apiofuranosyl-(1-->6)-beta-D-glucopyranoside (3), curculigoside (4), curculigoside B (5), curculigoside C (6), 2,6-dimethoxyl benzoic acid (7), and syringic acid (8)[11]. These antioxidative phenolic compounds possess several pharmacological activities such as antidiabetic, antimicrobial, and anticancer properties. The methanolic extract of root tubers of *C. orchioides* was determined to investigate their wound healing activity in experimentally induced diabetic mice.

2. Materials and methods

2.1. Collection and identification of plant material

The roots of *C. orchioides* were collected from the forest areas of Naugarh block in Chandauli district Uttar Pradesh, India. The plant was identified and authenticated by the Department of Botany, Banaras Hindu University, Varanasi. The material was shade dried, pulverized and preserved in air tight containers.

2.2. Extraction of plant material

2.2.1. Methanolic extraction

The methanolic extract of dried powder (1 kg) of the roots was prepared by using Soxhlet apparatus at 65 °C. The extracted materials was then kept in water bath to evaporate solvent totally and then kept on a rotary shaker at 190-220 r/min for 6 h to make the final volume one fourth of the original volume and stored at 4 °C in airtight bottles. The yield of the extract was 5.6 %. The methanolic extract was then subjected to phytochemical analysis and wound healing activity of diabetic mice.

2.2.2. Phytochemical analysis

Quantitative analysis of various phytochemicals such as alkaloids (Harbone, 1973), flavonoids (Boham and Kocipai, 1994), phenols (Harbone, 1973; Obadoni and Ochuko, 2001), saponin (Obadoni and Ochuko, 2001) and tannins (Van-Burden and Robinson, 1981) of roots of *C. orchioides* were performed.

2.3. Animals

All experiments were performed on 7 to 8 week-old male Swiss albino mice with an average weight of (25±1) g. The animals were individually kept under laboratory conditions at the Department of Biochemistry, Banaras Hindu University, Varanasi. The mice were divided into two groups diabetic (D) and non-diabetic (ND) comprising five animals in each group. The first five groups were considered as diabetic and assigned as DC, DM, DM+E_1, D+E_1 and D+E_2 where M for metformin and E_1 and E_2 respectively represented the different concentration of plant extracts. Diabetes was induced by giving intraperitonial streptozotocin injection (50 mg/kg body weight) in cold 0.1 mol/L citrate buffer, pH 4.5 for 5 consecutive days. The animals were confirmed for diabetes before the start of experiment. The serum glucose level was measured by glucose oxidase-peroxidase method using glucose test kit (Span diagnostics Ltd., India). The other five groups of mice were considered as non-diabetic and assigned as NDC, NDM, NDM+E_1, ND+E_1 and ND+E_2.

2.3.1. Wound creation

To develop wounds, a single full thickness 1.0 cm diameter superficial excision was made on the mid-dorsum of each diabetic and non-diabetic mouse at Day 0. The measurement

of the wound diameter was taken on Day 1, Day 7 and Day 13 by using transparency paper and permanent marker.

2.3.2. Extract administration

The DC and NDC (control), DM and NDM (60 mg/kg body weight in 200 μL ddH_2O), $DM+E_1$ and $NDM+E_1$ (30 mg/kg body weight metformin in 100 μL ddH_2O+100 mg/kg body weight extract in 100 μL ddH_2O), $D+E_1$ and $ND+E_1$ (200 mg/kg body weight extract in 200 μL ddH_2O), $D+E_2$ and $ND+E_2$ (400 mg/kg body weight extract in 200 μL ddH_2O) were injected for 14 consecutive days starting from Day 0 through intraperitoneal tube. The level of glucose, superoxide dismutase (SOD), LPO and nitric oxide (NO) were measured on 1st, 7th and 13th post wounding days of both diabetic and non-diabetic mice.

2.4. Determination of LPO and SOD activity

The levels of malondialdehyde (MDA) for LPO and SOD were estimated in the supernatant of wound tissue homogenates. To obtain supernatant, the homogenized wound tissues were centrifuged at 5000 r/min for 10 min to remove the cell debris. The level of MDA was estimated according to the method of Ohkawa *et al.*[12] and was expressed as nanomole per milliliter of MDA conjugate formed in the reaction. The estimation of SOD was done by the method of Mishra and Fridovich[13].

2.5. Determination of NOx activity

The levels of NOx were estimated by the method of Ghasemi *et al.*[14] and *Miranda et al*[15]. A total of 100 μL of tissue supernatant was mixed with Griess reagent [1% sulfanilamide, 0.1 % N-(1-naphthyl) ethylene diammine with 5% phosphoric acid] and OD was taken at 570 nm.

2.6. Statistical analysis

The data were analyzed by one way analysis of variance (ANOVA) using SNK test (Students-Newmann-Keuls) with sigma stat 3.5. The *P* value less then 0.05 were considered to be significant (level of significance *=0.05, **=0.01, ***=0.001). Data were represented as mean±SD. All the studies were performed in quadruplicate.

3. Results

3.1. Phytochemical analysis

The phytochemical analysis of *C. orchioides* revealed the presence of phenols, tannins, alkaloids, saponin and flavonoids. The presence of these phytochemicals were considered to be responsible for wound healing activity in diabetes (Table 1). The maximum saponin content (2.24%) was recorded in methanolic extract of root tubers of *C. orchioides*.

Table 1

Quantitative analysis of *C. orchioides* root tubers.

Plant	Alkaloids (%)	Phenols (%)	Tannin (%)	Flavonoids (%)	Saponin (%)
C. orchioides	1.29±0.12	1.46±0.03	0.05±0.09	1.35±0.22	2.24±0.02

3.2. Anti-diabetic plant extract decreases serum glucose level in diabetic mice

Administration of plant extract resulted in a significant decrease (P<0.001) in serum glucose level on Day 7 and 13 in case of diabetic mice as compared to the diabetic controls. A less significant decrease (P<0.05) was observed in case of mice treated with metformin on Day 7, but on Day 13, this decrease was highly significant (P<0.001) mice (Table 2).

Table 2

Level of serum glucose in various diabetic and non-diabetic groups of mice.

Groups	Level of serum glucose (mg/dL)		
	Day 1	Day 7	Day 13
NDC	122.00±3.10	112.00±3.14	109.00±3.45
NDM	125.00±3.13	120.00±4.26	111.00±3.65
$NDM+E_1$	124.00±3.82	118.00±3.46	110.00±4.32
$ND+E_1$	128.00±3.58	116.00±3.37	106.00±3.23
$ND+E_2$	121.00±3.12	109.00±3.18	102.00±3.41
DC	245.00±4.86	252.00±3.97	280.00±3.61
DM	220.00±3.24	175.00±3.79***	158.00±4.11***
$DM+E_1$	230.00±3.33	145.00±3.34*	138.00±3.41***
$D+E_1$	240.00±3.36	165.00±3.98	125.00±3.78
$D+E_2$	238.00±2.87	152.00±3.54	118.00±4.21

3.3. Calculation of wound contraction

The measurement of the wound areas were taken on the Day 1, 7 and 13 using transparency paper and a permanent marker. The wound areas were recorded and measured on graph paper. The plant extract increased the rate of wound healing in the diabetic mice. The wound closure was optimal in the diabetic group of $D+E_2$. The results are summarized in Table 3 and Figures 1-3.

Table 3

Wound diameter in various diabetic and non-diabetic groups of mice.

Groups	Wound contraction (mm^2)		
	Day 1	Day 7	Day 13
NDC	100.00±2.92	42.55±1.98	2.54±0.98
NDM	100.00±2.80	35.46±1.89	0.23±0.87
$NDM+E_1$	100.00±2.45	42.76±1.84	1.45±0.97
$ND+E_1$	100.00±2.67	50.87±1.99	0.93±0.78
$ND+E_2$	100.00±2.89	48.89±2.15	0.63±0.89
DC	100.00±2.81	78.32±1.96	58.56±1.95
DM	100.00±2.79	52.12±2.18	19.23±1.10
$DM+E_1$	100.00±2.65	79.54±2.26	20.54±1.06
$D+E_1$	100.00±2.98	56.32±2.07	13.64±0.99
D+E2	100.00±2.96	53.42±2.21	8.76±1.02

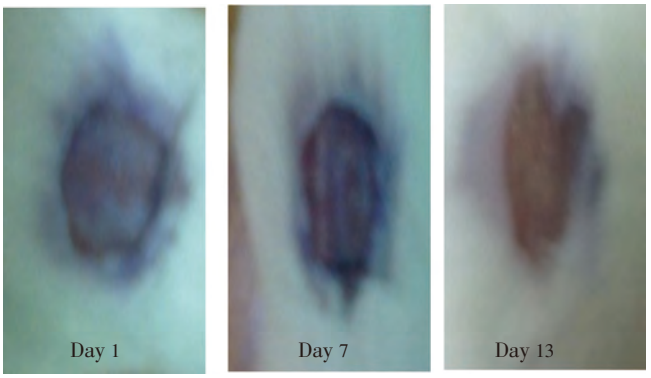

Figure 1. Photograph showing various stages of wound healing activity of diabetic control mice.

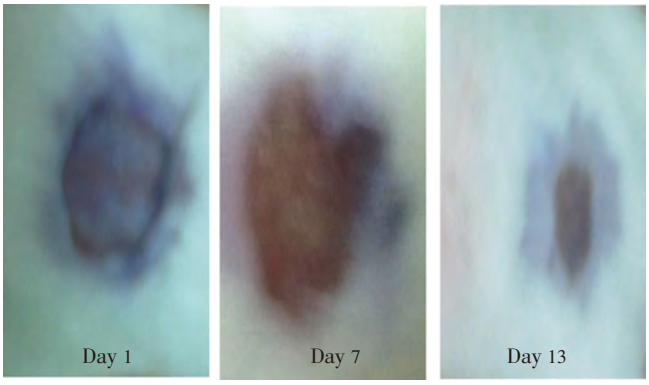

Figure 2. Photograph showing various stages of wound healing activity of *C. orchioides* extract at a dose of 200 mg/kg in streptozotocin induced diabetic mice.

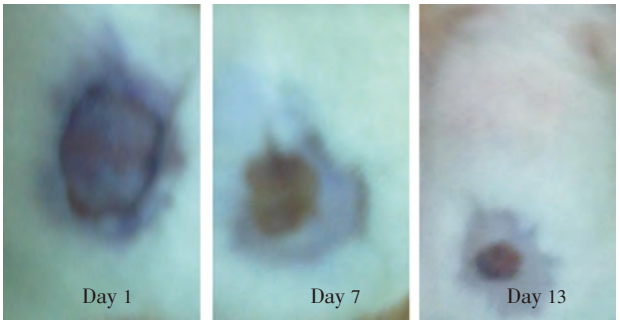

Figure 3. Photograph showing various stages of wound healing activity of *C. orchioides* extract at a dose of 400 mg/kg in streptozotocin induced diabetic mice.

3.4. Levels of SOD in wound tissue after extract administration

The wound tissue from diabetic mice showed decreased extracellular SOD activity as compared to non-diabetic mice. After plant extract administration, the SOD activity was found increased on both Day 7 and Day 13 in all diabetic groups beings significant. However, no significant changes were observed in non-diabetic groups. (Table 4)

3.5. Levels of LPO in wound tissue after plant extract administration

In diabetic wounds, the level of LPO in terms of MDA (nmol/mL) was increased as compared to non-diabetic wounds. The administration of plant extract was effective in preventing LPO as observed by decrease in the level of MDA content in diabetic groups. The decrease in the level of LPO in non-diabetic was not significant (Figure 4). The estimated levels of lipid oxidation in wound tissue supernatant from various diabetic and non-diabetic plant extract treated groups of mice were as depicted in Table 4.

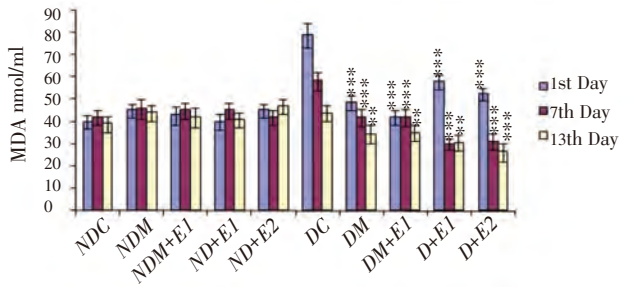

Figure 4. Effect of Curculigo ochioides plant extract of root tubers on level of lipid peroxidation (measured by MDA content and expressed as nanomole MDA per ml of wound tissue supernatant) in the diabetic and non-diabetic wound tissue.

3.6. Levels of NO in wound tissue after extract administration

The wound tissue from diabetic mice showed decreased nitric oxide level as compared to non-diabetic mice (Table 4). After plant extract administration, the NO was found increased significantly (P<0.001) on Day 7 and Day 13 in all diabetic groups being significant (Table 4).

4. Discussion

ROS is produced during normal cellular function. ROS is produced by neutrophils and other leukocytes damaged cells. It prevents cell proliferation and wound closure by damaging DNA, lipids, proteins, the extracellular matrix and cytokines that speed healing[16,17]. ROS includes hydroxyl radicals (OH), superoxide anion ($O_2^{\cdot-}$), hydrogen peroxide (H_2O_2) and NO[18,19]. They are very transient species due to their high chemical reactivity that leads to LPO and oxidation

Table 4
Level of SOD, LPO and NO in various diabetic and non-diabetic groups of mice.

Groups	Level of SOD[a]			Level of LPO[b]			Level of NO[c]		
	Day 1	Day 7	Day 13	Day 1	Day 7	Day 13	Day 1	Day 7	Day 13
NDC	1.40±0.12	1.24±0.11	1.45±0.10	40.00±3.12	42.00±3.24	39.00±3.45	31.20±2.12	40.00±2.87	42.00±2.15
NDM	1.20±0.10	1.33±0.14	1.34±0.16	45.00±3.23	46.00±4.32	44.00±3.65	34.00±2.43	42.00±2.9	44.00±2.78
$NDM+E_1$	1.35±0.15	1.37±0.12	1.33±0.12	43.00±4.12	45.00±3.56	42.00±4.32	35.00±2.23	43.00±2.41	45.00±2.93
$ND+E_1$	1.47±0.12	1.41±0.16	1.45±0.13	40.00±3.67	45.00±3.42	41.00±3.23	39.00±2.19	44.00±2.95	47.00±2.03
$ND+E_2$	1.22±0.17	1.32±0.17	1.33±0.18	45.00±3.04	42.00±3.21	47.00±3.41	38.00±2.76	46.00±3.03	47.40±2.07
DC	0.57±0.13	0.78±0.12	1.20±0.13	78.90±5.32	58.30±4.31	43.70±3.61	28.30±2.85	39.70±2.87	54.50±2.60
DM	0.64±0.11	1.13±0.15	1.53±0.14	48.40±3.24	41.90±3.87	34.30±4.11	35.20±2.54	41.80±2.51	49.70±2.81
$DM+E_1$	0.79±0.18	1.19±0.13	1.64±0.12	42.00±3.33	42.00±3.98	35.00±3.41	38.10±3.01	49.10±2.04	60.90±2.32
$D+E_1$	0.89±0.13	1.60±0.19	1.84±0.19	57.90±3.27	30.00±2.56	30.60±3.78	42.50±2.51	54.30±2.01	69.80±3.06
$D+E_2$	0.91±0.14	1.70±0.10	1.97±0.14	52.70±2.78	31.00±3.54	26.30±4.21	46.30±2.59	59.60±2.61	72.30±2.43

a: Level of SOD (inhibition percentage of NBT reduction/mL of wound tissue supernatant) from various diabetic and non diabetic groups of mice. b: Level of LPO in terms of MDA (nmol/mL of wound tissue supernatant from various diabetic and non-diabetic groups of mice. c: Level of total NO content (μmol/L) in wound tissue supernatant from various diabetic and non-diabetic groups of mice.

of DNA and proteins[20,21]. The role of oxygen-derived species in causing cell injury or death is increasingly recognized and linked to low antioxidant concentration[22].

The prevention of LPO is an essential process in all the aerobic organisms, as lipid peroxidation products can cause DNA damage[23]. Increased LPO and decreased antioxidant protection frequently occurs when ratio of ROS produced exceeds the level of antioxidants available. Such a reaction may lead to cytotoxicity, allergy, mutagenicity, carcinogenicity and delayed diabetic wound healing. Under normal conditions, antioxidant systems of the cell minimize the perturbations caused by ROS. When ROS generation is increased to an extent that it overcomes the cellular antioxidants, the result is oxidative stress. Antioxidants like SOD are substances that delay or prevent the oxidation of cellular oxidizable substrates from ROS species. The prevention of oxidation is an essential process in all the aerobic organisms. Nowadays in the field of biomedical sciences, plants are the potent source of antioxidant compounds that protect the cells from oxidative stress *in vitro*[24,25].

C. orchioides is one of the highly useful plants in the indigenous system of medicine for wound healing due to presence of natural antioxidative phenolic compounds[26-28]. *C. orchioides* contains a major group of phenolic glycosides compounds such as corchioside A, issocrassifoside G, curculigosaponin A-F, sitosterol, linolenic, palmitic acid & orcinol glucoside. These phenolic glycosides can significantly inhibit the generation of reactive oxygen species such as superoxide anion ($O_2^{\cdot-}$) and hydrogen peroxide (H_2O_2) that promote the delayed wound healing in diabetic condition[29-31].

The constituents such as alkaloids, triterpenoides and tannins of roots of *C. orchioides* may play a major role in the process of wound healing in diabetic rats. Tannins[32] and triterpenoides[17] are also known to promote the wound healing process mainly due to their astringent and antimicrobial property, which seems to be responsible for wound contraction and increased rate of re-epithelization. The vascular and lymphatic systems are of primary importance during the process of wound healing. Failure or delay of vascular regeneration decrease oxygen transport to the wound, which subsequently depresses the mobilization of excessive fluids from the wound site. The wound becomes edematous, leading to further damage, infection and eventually cell death. The roots of *C. orchioides* may thus achieve the following effects to improve tissue healing: an increased blood supply which increases the oxygen supply to the wound by blocking vasoconstructive compounds; greater migration of epidermal cells and extensive reorientation of collagen fibers caused by a stronger cross linking[33]. Several studies also reported this type of pro-healing action with the extract of many indigenous medicinal plants [34,35].

The results of this study can be justified by the facts that the methanolic extract of roots tubers of *C. orchioides* enhances the faster lay down of collagen fibers and improves the antioxidant status in the wound of diabetic animals.

In conclusion, the results of study showed that the extract of root tubers of *C. orchioides* effectively stimulate wound contraction as compared to control and other groups. This finding suggests the positive aspects of inclusion of this plant in management of diabetic wound healing.

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgements

The authors are thankful to Department of Biochemistry, Faculty of Science, Banaras Hindu University, Varanasi for providing the financial assistance and carrying out the biochemical investigations. This work is financially supported by Council of Scientific and Industrial Research (CSIR), Human Resource Development Group, Pusa, New Delhi, for Surabhi Bajpai (Senior Research Fellowship, File No. 9/13(295)/2010-EMR-1).

Comments

Background

This study was performed to calculate the effect of methanolic extract of *C. orchioides* on rate of wound contraction and estimation of various biochemical parameters such as SOD, LPO and NO levels in the granulation tissue of diabetic and non-diabetic mice.

Research frontiers

The methanolic extract of *C. orchioides* with the concentration of 200 mg/kg and 400 mg/kg body weight was induced through intraperitoneal injections in diabetic and non-diabetic mice. The results were compared with control and metformin induced diabetic and non-diabetic mice.

Related reports

The results showed that root tubers of *C. orchioides* are a potent source of antioxidative phenolic compounds that counteract with ROS species responsible for delayed wound healing. The root tubers of *C. orchioides* significantly increased the level of SOD, NO and decreased LPO in granuloma tissue of diabetic mice. Ozturk *et al.* studied the wound healing activity of *Hypericum perforatum* L. on chicken embryonic fibroblasts.

Innovations & breakthroughs

This study has showed that wound healing activity of *C. orchioides* in streptozotocin induced diabetic mice positively.

Applications

It is important to estimate and to monitor the role of

herbal medicine in the case of delay wound healing in diabetic persons.

Peer review

The is an interesting study in which the results suggested that *C. orchioides* promoted the faster wound healing in the case of diabetic persons due to present of flavonoides, tannin, *etc*.

References

[1] Dimitrios B. Sources of natural phenolic antioxidants. *Trends Food Sci Technol* 2006; **17**: 505-512.

[2] Gülçin Ý, Elias R, Gepdiremen A, Boyer L, Köksal E. A comparative study on the antioxidant activity of fringe tree (*Chion anthus* L.) extracts. *Afr J Biotechnol* 2007; **6**: 410-418.

[3] Kumaran A, Karunakaran RJ. Antioxidant and free radical scavenging activity of an aqu. extract of *Coleus aromaticus*. *Food Chem* 2006; **97**: 109-114.

[4] Gabriel A, Mussman J, Rosenberg LZ, de la Torre JI. Wound healing growth factors. New York: Medscape. [Online] Available from: http://emedicine.medscape.com/article/1298196-overview [Accessed on 27th August, 2013]

[5] Bailey AJ. Perspective article: the fate of collagen implants in tissue defects wound repair. *Wound Repair Regen* 2000; **8**: 5-12.

[6] Ruszczak Z. Effext of collagen matrices on dermal wound healing. *Adv Drug Deliv Rev* 2003; **55**(12): 1595-1611.

[7] Oztürk N, Korkmaz S, Oztürk Y. Wound healing activity of St. John′s Wort (*Hypericum perforatum* L.) on chicken embryonic fibroblasts. *J Ethnopharmacol* 2007; **111**: 33-39.

[8] Singh A, Singh PK. An ethnobotanical study of medicinal plants in Chandauli district of Uttar Pradesh, India. *J Ethnopharmacol* 2009; **121**: 324-329.

[9] Joy PP, Savithri KE, Mathew S, Skaria BP, Mathew G. *Curculigo Orchioides*: a plant for health care. *Indian J Arecanut Spices Med Plants* 2004; **6**: 131-134.

[10] Wang KJ, Li N. Antioxidant phenolic compounds from rhizomes of *Curculigo crassifoli*. *Arch Pharm Res* 2007; **30**(1): 8-12.

[11] Wu Q, Fu DX, Hou AJ, Lei GQ, Liu ZJ, Chen JK. Antioxidative phenols and phenolic glycosides from *Curculigo orchioides*. *Chem Pharm Bull* 2005; **53**(8): 1065-1067.

[12] Ohkawa H, Ohishi N, Yagi K. Assay for lipid peroxides in animal tissues by thiobarbituric acid reaction. *Anal Biochem* 1979; **95**(2): 351-358.

[13] Misra HP, Fridovich I. The role of superoxide anion in the autoxidation of epinephrine and a simple assay for superoxide dismutase. *J Biol Chem* 1972; **247**(10): 3170-3175.

[14] Ghasemi A, Zahedi Asl S, Mehrabi Y, Saadat N, Azizi F. Serum nitric oxide metabolite levels in a general healthy population: relation to sex and age. *Life Sci* 2008; **83**: 326-331.

[15] Miranda KM, Espey MG, Wink DA. A rapid, simple spectrophotometric method for simultaneous detection of nitrate and nitrite. *Nitric Oxide* 2001; **5**(1): 62-71.

[16] Kasote DM, Hegde MV, Deshmukh KK. Antioxidant activity of phenolic components from *n*-butanol fraction (PC-BF) of defatted flaxseed meal. *Afr J Food Technol* 2011; **6**(7): 604-612.

[17] Scortichini M, Pia Rossi M. Preliminary *in vitro* evaluation of the antimicrobial activity of triterpenes and terpenoids towards *Erwinia amylovora* (Burrll). *J Bacteriol* 2009; **71**: 109-112.

[18] Guo S and Dipietro LA. Factors affecting wound healing. *J Dent Res* 2010; **89**(3): 219-229.

[19] Goodson WH 3rd, Hunt TK. Wound healing and the diabetic patients. *Surg Gynecol Obstet* 1979; **149**: 600-608.

[20] Strodtbeck F. Physiology of wound healing. *Newborn Infant Nurs Rew* 2001; **1**: 43-52.

[21] Krishnan P. The scientific study of herbal wound healing therapies: current state of play. *Curr Anaesth Crit Care* 2006; **17**: 21-27.

[22] Apel K, Hirt H. Reactive oxygen species: metabolism, oxidative stress, and signal transduction. *Annu Rev Plant Biol* 2004; **55**: 373-399.

[23] Schultz GS. Molecular regulation of wound healing. In: Bryant RA, editor. *Acute and chronic wounds: nursing management*. 2nd ed. Philadelphia: WB Saunders Publisher; 1999, p. 413-429.

[24] Hong JS. Herbal, extract having therapeutic activity on injuries, and pharmaceutical composition and health food containing the same; 2006. [Online] Available from: http://www.freepatentsonline.com/7081259.html [Accessed on 15th August, 2013]

[25] Mandawade SD, Patil KS. Wound healing potential of some active principles of *Lawsonia alba* leaves. *Indian J Pharm Sci* 2003; **65**: 390-394.

[26] Nagesh KS, Shanthamma C. Antibacterial activity of *Curculigo orchioides* rhizome extract on pathogenic bacteria. *Asian J Microbiol Res* 2009; **3**(1): 5-9.

[27] Nayak S. Influence of ethanol extract of *Vinca rosea* on wound healing in diabetic rats. *Online J Biol Sci* 2006; **6**(2): 51-55.

[28] Madhavan V, Joshi R, Murali A, Yoganarasimhan SN. Antidiabetic activity of *Curculigo orchioides* root tuber. *Pharm Biol* 2007; **45**: 18-21.

[29] Rojkind M, Domininguez-Rosales JA, Nieto N, Greenwel P. Role of hydrogen peroxide and oxidative stress in healing responses. *Cell Mol Life Sci* 2002; **59**: 1872-1891.

[30] Alleva R, Nasole E, Di Donato F, Borghi B, Neuzil J, Tomasetti M. Alpha-lipoic acid supplementation inhibits oxidative damage, accelerating chronic wound healing in patients undergoing hyperbaric oxygen therapy. *Biochem Biophys Res Commun* 2008; **333**(2): 404-410.

[31] Gupta A, Singh RL, Raghubir R. Antioxidant status during cutaneous wound healing immunocompromised rat. *Mol Cell Biochem* 2002; **241**: 1-7.

[32] Ya C, Gaffney SH, Lilley TH, Haslam E. Carbohydrate-polyphenol complexation. In: Hemingway RW, Karchesy JJ, editors. *Chemistry and significance of condensed tannins*. New Yark: Plenum Press; 1988, p. 553.

[33] Johnson A. Towards rapid tissue healing. *Nurs Times* 1984; **4**: 39-43.

[34] Haque MM, Rafiq SS, Ahmed Q, Hasan, Mostofa M. Treatment of external wounds by using indigenous medicinal plants and patent extract in guinea pigs. *J Biol Sci* 2003; **3**: 1126-1133.

[35] Manjunatha BK, Vidya SM, Rasmi KV, Mankani KL, Shilpa HJ, Singh SJ. Evaluation of wound-healing potency of *Vernonia arborea* Hk. *Indian J Pharmacol* 2007; **37**: 223-226.