Evaluation of wound healing potential of a sea cucumber (Actinopyga mauritiana) extract in mice (Mus musculus)

ARFANI1, AHMAD RAIF1,2, CHRISMIS NOVALINDA GINTING1, REFI IKHTIARI1*

1Department of Biomedical Sciences, Faculty of Medicine, Universitas Prima Indonesia, Medan
2Department of Pathology, Faculty of Health Sciences, Universitas Imelda Medan, Medan

Abstract. Sea cucumbers are a marine source with biological activities that have been used in food as well as medicine in many Asian countries. Actinopyga mauritiana is one of the sea cucumber species with limited research about its bioactive activities. In this study, the wound healing activity of A. mauritiana extract in the form of cream, gel, and serum formulations in mice was investigated. The histopathology test was performed to evaluate the fibroblast and collagen dense levels in wound healing. Phytochemical screening has been carried out by the qualitative test of alkaloids, flavonoids, glycosides, steroids, and saponins compounds. The A. mauritiana ethanol extract (SCAE) was added into cream, gel and serum formulations with various concentrations (3, 6, and 9%) and applied to the wounded area of mice. The wound healing activities and histopathology results indicated that serum 9%-SCAE performed the highest decrease of wound length 0.55 ± 0.32 compared to other groups with a density level of fibroblast and collagen are 10.00 ± 1.00 and 10.67 ± 0.00, respectively. To the best of our knowledge, this is the first report on the wound healing activity of A.Mauritiana, which demonstrated promising therapeutic agents for wound healing and cosmetics applications in the future.

Keywords: Actinopyga mauritiana, wound healing, cream, gel, serum

INTRODUCTION

Sea cucumbers are marine invertebrates that have been consumed in Asia for centuries [1]. Sea cucumber is known as nutritional seafood that contains polyunsaturated fatty acids, amino acids, and bioactive contents. Moreover, sea cucumbers have attracted high attention in the biomedical field since their healing tissue capabilities due to the presence of bioactive compounds [2]. They have been used as a traditional remedy for healing wound activity in East and SouthEast Asia. Their secondary metabolites have been identified to induce tissue repair and wound healing processes especially triterpene glycosides (saponins) and glycosaminoglycan [3].

*Corresponding Author: refiikhtiari@unprimdn.ac.id
Received: February 2021 | Revised: October 2021 Accepted: October 2021

Wound healing is the tissue injury that includes the cellular phase (granulation), narrowing of wound area (wound contraction), collagen deposition, epithelial covering (epithelialization), and scar remodeling [4]. The new tissue formation is a complex process involving several steps; inflammation, angiogenesis, granulation tissue formation, re-epithelialization, and extracellular matrix (ECM) reconstruction [5]. After the skin being injured, proliferation occurred in cells (fibroblasts, keratinocytes, macrophages, and other immunes) then cells migrated to the wound site and a complex healing process began. In the wound healing process, the cell's migration towards the wound is known as one of the key phases managed by various stimulatory factors of tissue micro environments [6].

In the skin tissue, fibroblasts are the most abundant cells that play a critical role in wound healing, such as: rupturing of fibrin clots, generation of ECM components, and generation of collagen structure [7], [8]. Collagen synthesis
and granulation tissue formation also play an important role in wound contraction [9]. In contrast, free radicals inhibit the wound healing process that leads to impaired wound healing. It can disrupt dermal fibroblasts and keratinocytes functions by modifying or degrading ECM proteins. Moreover, ROS-mediated transcription can affect the secretion of proinflammatory cytokines and induction of matrix metalloproteinases [10].

Actinopyga mauritiana is a sea cucumber present in sand lagoons and seagrasses in the shallow reefs. This species belongs to the family the Holothuroidea and widely spread throughout the Red Sea to the Indo-Pacific Ocean [1], [11]. It has high protein and low-fat content and also becomes the highest commercial value among holothurians [1]. However, research on bioactivity from A. mauritiana is still limited. Since sea cucumbers have a high application to wound healing, thus this study aims to evaluate the wound healing potential of A. mauritiana. To the best of our knowledge, this is the first report of wound healing activities of ethanol extract of A. mauritiana sea cucumber on Mus musculus mice in cream, gel, and serum formulations.

METHODOLOGY

Sample preparation
Sea cucumbers A. mauritiana were obtained from Baitussalam, Aceh, Indonesia and were identified at the Research Center for Oceanography, Indonesian Institute of Sciences, Jakarta, Indonesia. 10,400 g of A. mauritiana were washed with distilled water, cleaned, and thinly sliced with a final weight of 5,300 g. The extraction process was done through maceration with 96% ethanol (2700 mL) for two days and filtered. This process repeated twice until the solution was clear. Then, the macerated solution was concentrated in a rotary evaporator at 40°C with 11.79 yield (% or 625.2 g crude extract. The extract was labeled as SCAE (Sea Cucumber A. mauritiana ethanol extract). Phytochemical screening was performed on the crude extract with the following standard procedures [12].

Formulations
Cream formulation based on Young [13] with modification stearic acid (12 wt%) and cetyl alcohol (0.5 wt%), followed by nipagine (0.1 wt%), triethanolamine (1 wt%), and sodium metabisulphite (0.2 wt%) were dissolved in distilled water. The gel formulation was prepared with slight modification [14]. A 1.25 g CMC-Na, nipagin (0.1 wt%), 2.5 g glycerin, 1.25 g of propylene glycol were mixed in 125 mL of distilled water. Serum formulation was composed of diluted xanthan gum (0.5 wt%), methylparaben (0.18 wt%), and propylparaben (0.02 wt%) were mixed into ethanol and propylene glycol (15 wt%). Then, each cream gel, and serum formulation was added with 3, 6, and 9% of SCAE.

Animals
Male mice (Mus Musculus) strain Double Ditsh Webster weights 20-25 g (6-8 weeks old) were selected and grouped into 10 groups (each group contained three mice). The mice were obtained from Balai Veteriner Medan which controlled under Institutional Animal Care and Use Committee (IACUC) guidelines of Indonesian Agency for Agricultural Research and Development. The animals were conditioned for a week for environmental conditions with ad libitum access to food and water. This study was approved by the Health Research Ethics Committee of Prima Indonesia University No 005/KEPK/UNPRI/I/2020.

Wound healing activity
To observe wound healing activity of sea cucumber extract, a previous method was followed with slight modification [15]. All of the experimental mice were anesthetized by local injection lidocaine hydrochloride (0.01 mL/100g BW). The hair on the dorsal side of mice was shaved and an excisional wound was inflicted (1 cm diameter and 0.2 cm depth). Then various concentrations of SCAE cream, gel, and serum (3%, 6%, and 9%) were applied to each group daily which was monitored for 14 days along with untreated group. For histopathology study, these mice were euthanized on the 15th day by inhalation of carbon dioxide followed by cervical dislocation [16]. The skin and subcutaneous tissue were dissected from the same wound area and incubated in 10% buffered formalin solution for 48 h. Each tissue was dehydrated in graded alcohol for 2 h and stained with hematoxylin and eosin according to standard procedure [15], [17].

Statistical analysis
All the results showed as mean ± Standard Error Mean. This study was measured by analysis of variance (ANOVA), followed by Post-Hoc Duncan and LSD tests. The values of *P<0.05 and **P<0.005 were considered to be statistically significant.
Evaluation of wound healing potential of a sea cucumber (Actinopyga mauritiana) extract in mice
(Arfani, Ahmad Raif, Chrismis Novalinda Ginting, Refi Ikhtiari)

RESULTS AND DISCUSSION

Phytochemical Screening
The result of phytochemical screening showed certain secondary metabolite compounds that present in SCAE as summarized in Table 1. The alkaloid tested by Mayer’s and Dragendroff’s reaction showed yellow-colored and orange precipitate, respectively.

Table 1 Phytochemical constituents of SCAE

| Compounds   | Result |
|-------------|--------|
| Alkaloids   | +      |
| Flavonoids  | +      |
| Glycosides  | +      |
| Saponin     | +      |
| Steroid     | +      |

+ = Present, - = Absent

Another test such as saponis exist with the appearance of stable foam after the reaction. Flavonoids were observed in the appearance of the orange color [18]. Molisch test showed the formation of a violet ring at the interface of the liquids as glycosides presence [19]. Steroids by Liebermann-Burchard reagent produce a greenish-blue color [20]. The crude extract of A. mauritiana contained several biocompounds that play an important role in the wound healing process. Flavonoids, part of phenolic compounds, known as best radical reducing power (e.g. DPPH and alkaloids) also have antioxidant activity and high anti-inflammatory [21]. Antioxidants play a role in accelerating the wound healing process by preventing reactive oxygen species (ROS) from penetrating the wound area [22]. Glycoside acts as an inhibitor of the collagenase and elastase enzyme activity, thus accelerating the wound healing process [23]. Kim [24] found that saponis help re-epithelialize wounds and inhibit inflammatory reactions during the early phase. Steroids are believed to speed up wound healing [25].

Wound Healing
Figure 1 shows all formulations with different concentrations contributed to wound healing activities for 14 days. Serum 9%-SCAE treatment has significantly decreased the wound size 0.55±0.32 cm and followed by cream 9%-SCAE 0.57±0.29 cm, serum 6%-SCAE 0.58±0.27 cm, and gel 9%-SCAE 0.59±0.29 cm. The wound length reduction of three formulations showed significant improvement compared to the untreated group. The density level of fibroblast and collagen in the wounded areas listed in Table 2. As expected from the treatments, untreated wounds gave the least collagen level than the others. Interestingly, the dense level of collagen for each formulation shows different. The cream formulation has the lowest level of collagen, followed by gel, and serum. Serum formulation shows the best result in collagen amount in wound area which gives wound healing rate in serum formulation better than other formulations. Collagen dense levels in serum 3% -SCAE equivalent to 6% -SCAE gel and close to 9% -SCAE cream (Table 2).
Table 2. Wound reduction; a score of fibroblast and collagen dense level after received SCAE treatments.

| Treatment   | Length of wounds (cm) | Fibroblast  | Collagen           |
|-------------|------------------------|-------------|--------------------|
| Untreated   | 0.79±0.15c             | 7.00±1.00a  | 2.67±1.00b         |
| Cream 3%    | 0.70±0.25d             | 6.33±0.58a  | 4.67±0.58c         |
| Cream 6%    | 0.63±0.26bc            | 7.33±0.58h  | 9.00±0.58a         |
| Cream 9%    | 0.57±0.29ce            | 9.00±0.00e  | 9.33±1.00ab        |
| Gel 3%      | 0.64±0.25d             | 6.33±0.58a  | 6.00±0.58d         |
| Gel 6%      | 0.60±0.27cd            | 8.67±0.58d  | 8.67±0.58e         |
| Gel 9%      | 0.59±0.29e             | 9.67±0.58ae | 10.33±0.58e        |
| Serum 3%    | 0.64±0.25ad            | 6.67±0.00a  | 8.67±0.58ae        |
| Serum 6%    | 0.58±0.27ce            | 8.33±0.00d  | 10.33±0.58ad       |
| Serum 9%    | 0.55±0.32e             | 10.00±1.00ed| 10.67±0.00e        |

Data are means ±SEM (n=3). Within a column, means bearing different superscripts are significantly different (P<0.05).

According to Mazliadiyana et al. [26] and Chaphalkar et al. [27], the fatty acid compound in sea cucumber plays an important role in the wound healing process. It has been reported that *A. mauritiana* contains high oleic acid among other Holothurians [28]. Oleic acid has anti-inflammatory capability in cutaneous lesions closure [29]. In another study using different species, methanol extracts of *Holothuria atra* showed antioxidant, anti-inflammatory, and analgesic activities [30]. Visual observation in Figure 2 depicted the contribution of treatments on wound creation-evolution from zero to the 14th day. Histopathology test showed serum 9%-SCAE has the highest score of fibroblast and collagen with 10.00 ± 1.00 and 10.67 ± 0.00, respectively (Table.2; Fig 3; Fig 4). It also showed a linear effect of SCAE concentration on wound size with incision length reduction. Fibroblasts play a vital role in the wound healing process that produces collagen during the tissue reconstruction process [31]. Fibroblasts have a contractile ability called myofibroblasts, which cause the wound edges to be drawn and closed [32]. The high dense fibroblasts induce collagen dense levels due to enhanced migration of fibroblasts in the treated area [33]. The proliferation occurred from the 7th to the 14th post-injury and the healing process will continue until the skin structure returns to normal.

Figure 2. Photographic representation of wound healing from 0 to 14th day with SCAE treatment.
Secondary metabolites such as steroids facilitated the anti-inflammatory effect [34], glycosides accelerated wound contraction [35], and flavonoids enhanced the number of fibroblasts [36]. Fibroblasts proliferation is stimulated by interleukin-1β (IL-1β), fibroblast growth factor (FGF), and platelet-derived growth factor (PDGF)[37]. Saponins increase fibroblast cell and macrophage number [38], [39] which is the major source of growth factors (FGF-2, GF, TGF-β) that contribute to proliferation [40]. TGF-β is charged in fibroblast activation and collagen deposition to form the epithelial layer. As a result, mucous epithelium and collagen layers were formed [41]. In addition, Bordbar et al [42] suggest that therapeutic effect of sea cucumber extract can be linked to the presence of bioactives such as assaponins and glycosides as antimicrobial agents. It may contribute to inhibiting the secondary infections caused by bacteria and fungi in the wound.

**CONCLUSION**

*A. Mauritiana* is rich in secondary metabolites such as alkaloids, flavonoids, glycosides, saponins, and steroids. The result shows that SCAE has significant wound healing activity on mice particularly in serum formulations. The secondary metabolites as bioactive compounds could be the reason for the wound healing activity of SCAE. However further studies need to be carried out to isolate and investigate the efficacy of all identified compounds and also the application for human used.

**ACKNOWLEDGMENT**

The authors would like to acknowledge Prima Indonesia University, University of Sumatera Utara, and Research Center for Oceanography, Indonesian Institute of Sciences, for the support and facilities. There is no funding supporting this work.
REFERENCE

[1] Oh, G.-W.; Ko, S.-C.; Lee, D. H.; Heo, S.-J.; Jung, W.-K. 2017. Biological activities and biomedical potential of sea cucumber (Stichopus japonicus): a review. *Fish. Aquat. Sci.* **20** (1) 28

[2] Pangestuti, R.; and Arifin, Z. 2018. Medicinal and health benefit effects of functional sea cucumbers. *J. Tradit. Complement. Med.* **8** (3) 341–351.

[3] Siahaan, E. A.; Pangestuti, R.; Munandar, H.; Kim, S.-K. 2017. Cosmeceuticals properties of sea cucumbers: prospects and trends. *Cosmetics* **4**(3) 26

[4] Rao, A. B.; Prasad, E.; Deepthi, S. S.; Haritha, V.; Ramakrishna, S.; Madhusudan, K.; Rao, Y. S. R. V. 2015. Wound healing: a new perspective on glucosylated tetrahydrocucurmin. *Drug Des. Devel. Ther.* **9** 3579–3588.

[5] Martin, P. 1997. Wound healing--aiming for perfect skin regeneration. *Science*, **276**(5309), 75-81.

[6] Guo, S. A.; and DiPietro, L. A. 2010. Factors affecting wound healing. *J. Dent. Res.* **89**(3), 219-229.

[7] Bainbridge, P. 2013. Wound healing and the role of fibroblasts. *J. Wound Care* **22**(8) 407—8; 410—412

[8] Schäfer, M.; and Werner, S. 2007. Transcriptional control of wound repair. *Annu. Rev. Cell Dev. Biol.* **23** 69-92.

[9] Ehrlich, H. P.; and Hunt, T. K. 2012. Collagen organization critical role in wound contraction. *Adv. wound care* **1**(1) 3-9.

[10] Moseley, R.; Stewart, J. E.; Stephens, P.; Waddington, R. J.; Thomas, D. W. 2004. Extracellular matrix metabolites as potential biomarkers of disease activity in wound fluid: lessons learned from other inflammatory diseases? *Br. J. Dermatol* **150**(3) 401-413.

[11] Eissa, S. H.; Omran, N. E.; Salem, H. K.; Kabbash, A. K.; Kandeil, M. A. 2017. Surveillance study on the most common sea-cucumbers in some Egyptian coasts. *Egypt. J. Exp. Biol.* **12** (2); 300–308.

[12] Kohndorff, M.; and Jain, D. K. 2017. Evaluation of wound healing activity and preliminary phytochemical screening of *Thespesia populnea* Bark Extracts. *UK J. Pharm. Biosci.* **5** 48-55.

[13] Young, A. E.. 1972. Practical Cosmetic Science. London: Mills and Boon Ltd.

[14] Maswadeh, H. M.; Semreen, M. H.; Naddaf, A. R. 2006. Anti-inflammatory activity of Achillea and Ruscus topical gel on carrageenan-induced paw edema in rats. *Acta Pol Pharm.* **63**(4), 277-280.

[15] Rosa, S. A.; Adi, S.; Achadiyani, A.; Hairani, A. F.; Lantika, U. A. 2018. Efek gel canting kuning (*Solamun tuberosum L*) terhadap proses penyembuhan luka pada mencit (*Mus musculus*). *Glob. Med. Heal. Commun.* **6**(1) 21-27.

[16] Bellare, A.; Epperly, M. W.; Greenberger, J. S.; Fisher, R.; Glowacki, J. 2018. Development of tensile strength methodology for murine skin wound healing. *MethodsX* **5** 337-344.

[17] Aravinthan, A.; Park, J. K.; Hossain, M. A.; Sharmila, J.; Kim, H. J.; Kang, C. W.; Kim, J. H. 2018. Collagen-based sponge hastens wound healing via decrease of inflammatory cytokines. *J Biotech* **8**(12) 1-9.

[18] Parbuntari, H.; Prestica, Y.; Gunawan, R.; Nurman, M. N.; Adella, F. 2018. Preliminary phytochemical screening (qualitative analysis) of cacao leaves (*Theobroma cacao L*). *Eksakta Berk. Ilm. Bid. MIPA* **19**(2) 40-45.

[19] Kumar, B. A.; Lakshman, K.; Velmurugan, C.; Sridhar, S. M.; Gopisetty, S. 2014. Antidepressant activity of methanolic extract of *Amaranthus spinosus*. *Basic Clin. Neurosci.*, **5**(1) 11-17.

[20] Xiong, Q.; Wilson, W. K.; Pang, J. 2007. The Liebermann–Burchard reaction: sulfonation, desaturation, and rearrangement of cholesterol in acid. *Lipids*, **42**(1), 87-96.

[21] Gutiérrez, D. M. A.; Bah, M., Garduño, M. L. R.; Mendoza, S. O. M.; Serrano, V. C. 2014. Anti-inflammatory and antioxidative activities of methanol extracts and alkaloid fractions of four Mexican medicinal plants of Solanaceae. *African J. Tradit. Complement. Altern. Med.* **AJTCAM** **11**(3) 259-267.

[22] Barku, V. Y. A. 2019. *Wound Healing: Contributions from Plant Secondary Metabolite Antioxidants*; 1st Edito.; K. Hakan; Ed. Rijeka: IntechOpen p. Ch. 5. Özbilgin, S.; Acikara, Ö. B., Akkol, E. K., Süntar, I., Keleş, H., & İşcan, G. S. (2018). In vivo wound-healing activity of *Euphorbia characias* subsp. wulfenii: Isolation and quantification of quercetin glycosides as bioactive compounds. *J. Ethnopharmacol.* **224** 400-408.

[23] Kim, Y. S.; Cho, I. H.; Jeong, M. J.; Jeong, S. J.; Nah, S. Y.; Cho, Y. S.; Bae,
Evaluation of wound healing potential of a sea cucumber (Actinopyga mauritiana) extract in mice... (Arifani, Ahmad Raif, Chrismis Novalinda Ginting, Refi Ikhtiari)

C. S. 2011. Therapeutic effect of total ginseng saponin on skin wound healing. *J. Ginseng Res.* 35(3), 360.

[25] Bosanquet, D. C.; Rangaraj, A.; Richards, A. J.; Riddell, A.; Saravolac, V. M.; Harding, K. G. 2013. Topical steroids for chronic wounds displaying abnormal inflammation. *The Annals of R. Coll. Surg. Engl.* 95(4) 291-296.

[26] Mazliadiyana, M.; Nazrun, A. S.; Isa, N. M. 2017. Optimum dose of sea cucumber (*Stichopus chloronotus*) extract for wound healing. *Med Health Sci.* 12(1) 83-89.

[27] Chaphalkar, R.; Apte K. G.; Talekar, Y.; Ojha, S. K.; Nandave, M. 2017. Antioxidants of *Phyllanthus emblica* L. Bark extract provide hepatoprotection against ethanol-induced hepatic damage: a comparison with silymarin. *Oxid. Med. Cell. Longev.* 2017 3876040;

[28] Omran, N. E. S. E. S. 2013. Nutritional value of some Egyptian sea cucumbers. *African J. Biotechnol.* 12 5466–5472.

[29] Donato-Trancoso, A.; Monte-Alto-Costa, A.; Romana-Souza, B. 2016. Olive oil-induced reduction of oxidative damage and inflammation promotes wound healing of pressure ulcers in mice. *J. Dermatol. Sci.* 83(1) 60-69.

[30] Dhinakaran, D. I.; Lipton, A. P. 2014. Bioactive compounds from Holothuria atra of Indian ocean. *SpringerPlus* 3(1) 1-10.

[31] Tracy, L. E.; Minasian, R. A.; Caterson, E. J. 2016. Extracellular matrix and dermal fibroblast function in the healing wound. *Adv. wound care* 5(3) 119-136.

[32] Theoret, C. 2016. Physiology of Wound Healing; Equine Wound Management. pp. 1–13.

[33] Bolla, S. R.; Al-Subaie, A. M.; Al-Jindan, R. Y.; Balakrishna, J. P.; Ravi, P. K.; Veeraraghavan, V. P.; Surapaneni, K. M. 2019. In vitro wound healing potency of methanolic leaf extract of Aristolochia saccata is possibly mediated by its stimulatory effect on collagen-I expression. *Heliyon* 5(5) e01648.

[34] Saqallah, F. G.; Hamed, W. M.; Talib, W. H. 2018. In Vivo Evaluation of Antirrhinum majus’ Wound-Healing Activity. *Sci. Pharm.* 86(4) 45.

[35] Arundina, J.; Yuliati, Y.; Soesilawati, P.; Damiaryanti, D. W.; Maharani, D. 2015. The effects of golden sea cucumber extract (*Stichopus hermanii*) on the number of lymphocytes during the healing process of traumatic ulcer on wistar rat’s oral mucous. *Dent. J. Maj. Kedokt. Gigi* 48(2) 100-103.

[36] Aslam, M. S.; Ahmad, M. S.; Riaz, H.; Raza, S. A.; Hussain, S.; Qureshi, O. S. Javed, O. 2018. Role of flavonoids as wound healing agent in *Phytochemicals*; T. Asao and M. Asaduzzaman; Eds. Rijeka: IntechOpen; 97–102.

[37] Dehkordi, A. N., Babaheydari, F. M., Chehelgerdi, M., & Dehkordi, S. R. 2019. Skin tissue engineering: wound healing based on stem-cell-based therapeutic strategies. *Stem Cell Res. Ther.* 10(1) 1-20.

[38] Apriasari, M. L., Puspitasari, D., Rahayu, R. P., & Ernawati, D. S. (2018). The effect of musa acuminata stem in increasing macrophage and neovascular cells of healing process. *Padjadjaran J. Dent.* 30(2) 103-108.

[39] Lordani, T. V. A.; de Lara, C. E.; Ferreira, F. B. P.; de Souza Terron Monich, M.; Mesquita da Silva, C.; Felicetti Lordani, C. R.; Lonardoni, M. V. C. 2018. Therapeutic effects of medicinal plants on cutaneous wound healing in humans: a systematic review. *Mediators Inflamm.* 2018 7354250

[40] Minutti, C. M.; Knipper, J. A.; Allen, J. E.; Zaiiss, D. M. 2017, January. Tissue-specific contribution of macrophages to wound healing. In *Seminars in cell & developmental biology* 61, pp. 3-11. Academic Press.

[41] Khoswanto, C.; Juliastuti, W. S.; Adla, K. A. 2018. The effect of Avocado leaf extract (*Persea americana Mill.*) on the fibroblast cells of post-extraction dental sockets in Wistar rats. *Dent. J.* 51(3), 129-132.

[42] Bordbar, S.; Anwar, F.; Saari, N. 2011. High-value components and bioactives from sea cucumbers for functional foods—a review. *Mar. drugs* B(10) 1761-1805.