GSC Biological and Pharmaceutical Sciences

eISSN: 2581-3250 CODEN (USA): GBPSC2

Cross Ref DOI: 10.30574/gscbps

Journal homepage: https://gsconlinepress.com/journals/gscbps/

(REVIEW ARTICLE)

Check for updates

Role of *Cannabis sativa* on wound healing: An update

Kiran P. Kolkar [1], Ravindra B. Malabadi [2, 3, *] and Raju K. Chalannavar [2]

[1] *Department of Botany, Karnatak Science College, Dharwad-580003, Karnataka State, India.*

[2] *Department of Applied Botany, Mangalore University, Mangalagangotri-574199, Mangalore, Karnataka State, India.*

[3] *Miller Blvd, NW, Edmonton, Alberta, Canada.*

GSC Biological and Pharmaceutical Sciences, 2025, 32(03), 088–102

Publication history: Received on 13 July 2025; revised on 10 August 2025; accepted on 01 September 2025

Article DOI: https://doi.org/10.30574/gscbps.2025.32.3.0330

Abstract

Wound healing is one of the most complex and essential treatments in the human body and still remains a challenge in the healthcare system. Hemp-based materials are regarded as important components of wound dressings. Cannabidiol (CBD) and cannabis-based therapies may protect against oxidative stress, potentially reducing inflammation and cell damage in the chronic wound microenvironment and the surrounding tissues. Cannabis oil stands out in the realm of wound care due to its unique combination of antimicrobial, anti-inflammatory, and antioxidant properties. Cannabis oil offers a holistic approach to managing inflammation, minimizing systemic exposure, and promoting overall skin health and regeneration. Wound dressings are essential for maintaining a moist environment and protecting the wound; however, they can benefit from the addition of cannabis oil, which can enhance their effectiveness by providing added anti-inflammatory and antimicrobial support. In vitro studies have offered a variety of targets in which cannabis containing compounds may influence wound healing. Overall, these studies suggest a positive effect on wound healing by cannabinoids. CBD oil can be used as a remedy for skin lesions. Hydrogel composite prepared from bio-based materials is therefore considered as a promising route. However, further clinical research is needed to fully understand the mechanisms involved and to optimize the therapeutic applications of cannabis oil in wound care. Further research is needed to understand the full spectrum of side effects of topical cannabinoids.

Keywords: Acute Pain; Cannabinoids; Cannabis Oil; Chronic Wound; Hydrogel; Skin Injuries; Wound Healing

1. Introduction

A wound is defined as the breakage in the continuity of the skin. Wound healing is a dynamic process and many cellular players and structures are involved in the process. In general, wound healing process has several phases: (1) homeostasis/coagulation, (2) inflammatory cell recruitment, (3) proliferative phase and (4) maturation phase [45-53]. A wound may also be defined as an interruption within the continuity of the epithelial lining of the skin or mucosa that occurs as a result of physical or thermal damage [46-53]. Wound healing represents an important medical problem [46-53]. Fibrosis and tissue regeneration are opposite processes related with wound repair [46-53]. Human skin is an important interface between the environment and the human body and is inhabited by diverse and complex microbial communities, whose health impacts are still not clear [45-53]. Many factors in the wound healing process are still not well understood, but the role of the Mesenchymal stem/stromal cells (MSCs) in the process seems to be useful [46-53-94]. These cellular and molecular events are highly coordinated and controlled. For effective tissue repair and restoration of tissue function, there is a need for alteration of actin cytoskeleton as well as secretion of extracellular matrix (ECM) proteins and integrin receptors [46-53, 93-94]. Wound healing is one of the most complex and essential treatments in the human body and still remains a challenge in the healthcare system [46-53]. The skin can prevent most external pathogens from attacking the human body and keep the human body healthy [45-53]. However, it is susceptible to injury and bacterial infection, which can lead to various diseases [46-53, 93]. Wound healing is a vital

* Corresponding author: Ravindra B. Malabadi

natural physiological response to tissue damage consisting of the collaboration of many cell strains and their products [46-53]. In general, antimicrobial action is a current focus in wound healing and biomedical devices [46-53, 93]. The antimicrobial wound dressing can be intrinsic, with the dressing material itself, or can be engineered with antimicrobial molecules by adding an antibiotic agent to a polymer backbone or in the form of nanoparticles or chemicals linked to a polymer surface [46-53].

In general, there are different types of wounds such as acute wounds, closed wounds, open wounds, incised wounds, tear or laceration wounds, puncture wounds, abrasive or superficial wounds, penetration wounds, gunshot wounds and chronic wounds [46-53, 93]. Open wounds are usually accompanied by bleeding and are associated with rupturing layers of the skin [46-53, 93]. Closed wounds resulted from bruising or dead blood and crashes [46-53, 93]. The wound healing and repair bring an immense burden economically and socially to the patient [46-53]. The wound healing process is associated with cell migration and proliferation, extracellular matrix remodeling, angiogenesis and re-epithelialization. In normal conditions, a wound will lead to healing, resulting in reparation of the tissue [46-53, 93]. Several risk factors, chronic inflammation, and some diseases lead to a deficient wound closure, producing a scar that can finish with a pathological fibrosis [46-53]. Mesenchymal stem/stromal cells (MSCs) are widely used for their regenerative capacity and their possible therapeutically potential [46-53, 93].

Chronic wounds are particularly challenging to treat as they remain susceptible to pathogenic microbes, including antimicrobial-resistant strains, resulting in localized and potentially fatal systemic infections [54–90, 93]. The rise in antimicrobial resistance exacerbates these challenges, leading to treatment failures, prolonged morbidity, and increased healthcare expenditures [54–90]. Despite this pressing need, the development of new antimicrobials remains slow [54–90, 93]. Current treatments for chronic wounds include conventional antibiotic therapy, wound dressings, hyperbaric oxygen therapy, and negative-pressure wound therapy, alongside advanced methods such as skin grafting, growth factor supplementation, collagen sponges, and tissue-engineered products [54–93]. These methods are often labour-intensive, technologically sophisticated, and less accessible in resource-poor settings [54–90]. Topical agents with antibacterial properties offer advantages in wound management, facilitating rapid healing without systemic effects and ensuring better compliance [54–90, 93, 94].

2. Cannabis sativa: Phytochemistry and Pharmacology

Cannabis sativa L., belongs to *Cannabaceae* family is one of the oldest medicinal plant was found as wild noxious weed particularly in Indian Himalayan Region, Asian countries, China, Pakistan, Nepal, Bhutan, Afghanistan, Morocco, Iran and African countries [1-44, 92, 93]. *Cannabis sativa* has been used for thousands of years for recreational, medicinal, or religious purposes. *Cannabis sativa* is also a wild noxious weed with notorious psychoactive principle (THC) found growing in all the parts of India. *Cannabis sativa L.* with a diverse mixture of chemical constituents, creating a complex matrix [1-44]. Terpenes, phenols, fatty acids, amino acids, flavonoids, sugars, phenolic compounds, hydrocarbons, and phycannabinoids are only a few of the estimated 500 distinct ingredients [1-44, 92, 93, 94]. *Cannabis sativa* is known for the accumulation of secondary metabolites, the phytocannabinoids as a part of its own defensive mechanism [1-44, 92-94]. *Cannabis sativa* is a psychoactive plant that contains more than 500 different chemical compounds, of which phytocannabinoids are the main constituents [1-44]. These molecules are produced through the secondary metabolism, and their concentration varies between the different subspecies, age, harvesting time, and growing conditions [1-44, 92, 93, 94, 95]. *Cannabis sativa* has gained a lot of popularity in the last few decades for not only being an illicit drug but for its medicinal values from ancient times and a potential source for modern drugs to treat several targets for human wellness [1-44]. The pharmacologic and therapeutic properties of preparations of *Cannabis sativa* and Δ-9-THC (**Δ**9-tetrahydrocannabinol) its most psychoactive compound, have been extensively reviewed [1-39]. There is still a huge prejudice in society in relation to Medical *Cannabis sativa* L.(drug type or marijuana) due to its recreational use [1-44, 92, 93].

Female *Cannabis* flowers have densely packed glandular structures called trichomes that store the phytocannabinoids, tetrahydrocannabinolic acid (THCA) and Cannabidiolic acid (CBDA) which must be decarboxylated by heat to produce Δ9-tetrahydrocannabinol (THC: intoxicating) and Cannabidiol (CBD: non-intoxicating) [1-35]. The two cannabinoids the most well known for their therapeutic properties are, Δ9-tetrahydrocannabinol (THC) and Cannabidiol (CBD) [1-44, 92, 93]. THC and CBD are the neutral homologs of tetrahydrocannabinolic acid (THCA) and Cannabidiol acid (CBDA) respectively [1-35]. A conventional classification model of Cannabinoids is due to their chemical contents dividing them to eleven subclasses including Cannabigerol (CBG), Δ9-tetrahydrocannabinol (Δ9-THC), Cannabidiol (CBD), Cannabichromene (CBC), Cannabinol (CBN), (−)-Δ8-transtetrahydrocannabinol (Δ8-THC), Cannabicyclol (CBL), Cannabinodiol (CBND), Cannabielsoin (CBE), Cannabitriol (CBT) and miscellaneous [1-44, 92, 93, 94, 95].

Cannabis spp. are native to the Indian sub-continent and required warm temperatures and high light intensity to achieve good yields [1-44, 92, 93]. Humans have a long history with *Cannabis sativa*, with evidence of cultivation dating back as far as 10,000 years [1-44]. The World Health Organization (WHO) reported that *Cannabis sativa* is the most widely cultivated, trafficked and abused illicit drug, and it constitutes over half of worldwide drug seizures [1-44, 92, 93]. Medical research on *Cannabis sativa* has primarily focused on isolated THC (Δ9-Tetrahydrocannabinol), and CBD (Cannabidiol) but there are hundreds of other chemical constituents in cannabis, including cannabinoids and terpenes [1-44, 92, 93]. *Cannabis sativa* existed prior to the development of agriculture, which began about 13 000 years ago [1-44, 92, 93]. Therefore, it is assumed to have been one of the most critical crops for the development of civilization [1-44]. Humans across different eras have utilized it for a variety of applications, such as nutrition, recreation, generation of seed oil and fibre for industrial purposes, religious and spiritual practices and medicine [160]. Therefore, *Cannabis sativa* is one of the oldest medicinal plant on earth [1-44, 92, 93, 94]

Cannabis sativa has a long history in India, recorded in legends and religion [1-44]. According to *Ayuverda* in India, the medicinal value of the *Cannabis sativa* plants was well documented as Vijaya and often known as Desi Vijaya [1-44, 92, 93]. The meaning of Vijaya is nothing but a Victory [1-44]. This was the first Indian written evidence to support the medicinal value of *Cannabis* plants which was well documented in *Ayuverda* in India [1-44]. The earliest written reference to cannabis in India may occur in the *Atharvaveda*, dating to about 2500 BCE [1-44]. Initial uses of cannabis date back to almost 5000 years in India which was well documented in A*yurveda* now cultivated for both medicinal and recreational applications [1-44, 92, 93-95]. It is found in various habitats ranging from sea level to the temperate and alpine foothills of the Indian Himalaya Region from where it was probably spread over the last 10,000 years [1-44]. Therefore, medicinal uses of *Cannabis* might have started from Indian Himalayan civilization and moved to another civilization through consecutive millennia [1-44]. Many of the historians believed that Indian Himalayan Region was the centre of origin of *Cannabis sativa* and *Cannabis indica* [1-44, 92, 93, 94,95].

Cannabis sativa is also known as the Pot gold of Indian Himalayan Region (1-44). Many 19th-century practitioners described medicinal properties to *Cannabis sativa* after the drug found its way to Europe during a period of colonial expansion into Africa and Asia [1-44]. For example, William B. O'Shaughnessy, an Irish physician working at the Medical College and Hospital in Calcutta, West Bengal, India first introduced *Cannabis sativa* (Indian hemp) to Western medicine as a treatment for tetanus and other convulsive diseases [1-44]. Tribal people in the Himalayan region used cannabis as a homemade herbal medicine for many diseases. During, Covid-19, the infusion of *Cannabis sativa* flower with a morning cup of tea has saved the life of many people [1-44]. *Cannabis sativa* oil was used as dengue mosquito repellent for controlling dengue viral fever, bacterial infections and fungal diseases [1-44, 92, 93].

Introduced into Western medicine by William O'Shaughnessy in 1838 to treat a variety of conditions, including rheumatic pain and epilepsy, the use of cannabinoids (CBs) in clinical practice entered a period of latency and oblivion due to political barriers and problems in establishing quality control [1-44]. Cannabis was (re) introduced into British medical practice in the early 1840's by Irish physician Dr. William O'Shaughnessy, an army surgeon serving in Calcutta, India [1- 44]. In the Victorian period, cannabis was widely used for a variety of ailments, including muscle spasms, menstrual cramps, rheumatism, the convulsions of tetanus, rabies, and epilepsy, and as a sedative [1-35]. *Cannabis sativa* extracts were typically administered orally in the form of an alcoholic tincture and were commonly incorporated in proprietary medicines [1-44]. With the introduction of synthetic drugs, herbal remedies were increasingly viewed as unpredictable and many of them, including cannabis extracts and tinctures, were removed from the British Pharmacopoeia of 1932 but retained in the British Pharmaceutical Codex of 1949[1-44, 92, 93].

Cannabis sativa L., is classified into two types as 1) Industrial *Cannabis sativa*, hemp or fiber type, and 2) Medical *Cannabis sativa* L. (drug type or marijuana) based on its Λ9-tetrahydrocannabinol (THC) content [1-44]. Medical *Cannabis sativa* (drug type or marijuana) contains very high levels of THC (above 0.3 to 38% of dry weight) and grown inside the greenhouse-controlled conditions for the production of unfertilized female flowers containing very higher levels of THC [1-44, 92, 93]. As of March, 2025, sales and cultivation of Medical *Cannabis sativa* L.(drug type or marijuana) are **illegal** in India and considered as the narcotic substance. The import and export of Medical *Cannabis sativa* L. (drug type or marijuana, Charas, Ganja, Bhang) into India was entirely prohibited by the Government of India nearly two decades ago. The consumption of *Cannabis sativa* resin (Charas) is prohibited and banned everywhere in India [1-44, 92, 93].

Industrial *Cannabis sativa* L. (Hemp or fiber type) and Medical *Cannabis sativa* (drug type or marijuana) share the same species, *Cannabis sativa* L, but represent different varieties [1-35]. As such, there are genetic differences that lead to different chemical characteristics, which, in turn, lead to different uses [1-44]. Industrial hemp or fibre *Cannabis sativa* is grown outside in a large agriculture land for the stalk and seeds, and maximizing yields results. in tall plants with few leaves [1-44]. On the other hand, Medical *Cannabis sativa* (Marijuana or drug type), is grown under controlled conditions in a green house conditions for its leaves and female unfertilized flower known for the parts of the plant with the largest concentrations of THC [1-44]. As a result, Medical *Cannabis sativa* (drug type or marijuana) grown for its psychoactive properties (THC) is generally managed to control height and increase bushiness: that is, encouraging many leaves and branches, thus leading to more flowers and buds [1-44]. *Cannabis sativa* varieties also vary by planting density: Medical *Cannabis sativa* (drug type or marijuana) plants are spaced to allow bushiness while Industrial *Cannabis sativa* L. (Hemp or fiber type) plants are planted much closer together to discourage branching and flowering [1-44]. Harvest timing and strategies also vary by variety, again allowing for detection of intended use [1-44, 92, 93].

Λ9-tetrahydrocannabinol (THC) is the narcotic chemical most responsible for the psychoactive properties in Medical *Cannabis sativa* L.(drug type or marijuana). Industrial hemp has traditionally been defined as having less than 0.3 percent THC, although in some U.S. states it is now defined as having no more than 0.5 % percent THC [1-44]. They have also established a maximum standard of 10 parts per million (ppm) for THC residue in hemp products, including grain, flour, and oil (Agriculture and Agri-Food Canada 2013) [1-44]. However, due to the presence of psychoactive molecules, Λ9-tetrahydrocannabinol (Λ9-THC) and Λ8-tetrahydrocannabinol (Λ8-THC), cannabis cultivation and its use is restricted/regulated in many countries [1-44]. The official discovery of Δ9-tetrahydrocannabinol (THC) is commonly attributed to Dr. Raphael Mechoulam affectionately referred to as the Godfather of Cannabis Science [1-44]. Δ9-tetrahydrocannabinol (THC) was discovered in 1964 by Dr. Raphael Mechoulam and his colleagues at Israel's Weizmann Institute of Science [1-44]. The credit of the discovery of Cannabidiol (CBD) in 1963 and Δ9-tetrahydrocannabinol (THC) in 1964 isolated from *Cannabis sativa* attributed to Dr. Raphael Mechoulam and his team [1-44].

Today *Cannabis sativa* continues to be the most used drug in the world[1-44]. Research showed that cannabis use is associated with a wide range of adverse health consequences that may involve almost every physiological and biochemical system including respiratory/pulmonary complications such as chronic cough and emphysema, impairment of immune function, and increased risk of acquiring or transmitting viral infections such as HIV, HCV, and others [1-44, 92, 93]. Both Medical *Cannabis sativa* (Marijuana or drug type) and Industrial *Cannabis sativa* (hemp or fiber type) is used for controlling numerous diseases, such as chronic pain, asthma, rheumatoid arthritis (RA), **wound** healing, constipation, multiple sclerosis (MS), cancer, inflammation, glaucome, neurodegenerative disorders (Epilepsy-seizure disorder, Alzheimer's disease, Parkinson's disease, dengue viral disease, Huntington's disease, Tourette's syndrome, Dystonia, Lennox-Gastaut Syndrome (LGS) and Dravet Syndrome (DS), Obesity, weight loss, anorexia, and emesis, osteoporosis, schizophrenia, cardiovascular disorders, sleep disorders, Traumitic brain injury (TBI), Post traumetic stress injury, drug addiction (Marijuana), AIDS Wasting syndrome, Amyotrophic lateral sclerosis (ALS), depression and anxiety, diabetes, migraine (headache disorder), Covid-19 (SARS-CoV-2), Leishmaniasis (Kala-Azar), dengue fever, monkeypox, Nipah virus, Lumpy skin vital disease of cattle, and metabolic syndrome related disorders, are being treated or have the potential to be treated by cannabinoid agonists/ antagonists/cannabinoid-related compounds [1-44, 92, 93,94, 95].

3. Wound Healing: Role of *Cannabis sativa*

Wound healing is a complex biological process involving four sequential and overlapping phases, haemostasis, inflammation, proliferation, and remodelling, which are mediated by various cellular and molecular events to restore tissue integrity [45–60]. Oxidative stress (OS) plays a crucial role in regulating wound healing. Research over the past decade shows that OS can have both positive and negative effects on wound healing, depending on its context [45–90]. In mammals, OS arises from either an overproduction of ROS or a reduction in antioxidant defense mechanisms [45–90-93]. Excessive and uncontrolled oxidative stress is a key factor in both sustaining and disrupting inflammatory processes, which are critical in the development of chronic non healing wounds [45–90-93]. The excessive formation and accumulation of ROS beyond the cellular capacity to neutralize them can impede the transition of injured tissue from the inflammatory phase to the proliferative phase of wound healing [45–90]. As a result, prolonged inflammation in the wound area disrupts the healing process of skin [45–90]. Maintaining a balance in the redox (reduction–oxidation) within cells can help prevent abnormal cell growth and immune dysregulation [45–90]. Scientific studies have demonstrated that antioxidants can speed up wound recovery, particularly in cases of chronic wounds [45–90-93].

As the largest organ in the human body, skin is the essential barrier for protecting the body against germs, various injuries, hazardous substances, and external damaging factors [45–90]. Beyond this, skin plays crucial roles in vitamin D production, body moisture and temperature regulation, and sensation, making skin damage and loss a critical health issue [45–90]. Skin wounds are injuries to the skin resulting from disease, infection, mechanical, chemical, or thermal damage and can be acute or chronic [45–90]. Wound management is a complex process that varies based on the wound type, size and location, and patient characteristics, but in most cases, it involves the application of dressings that modulate the wound environment, with or without surgical intervention [45–90]. Wound dressings range widely in their structure, composition, and mechanism of action and can serve a range of functions, including protection of the wound site from further injury and pathogens, creating a moist wound environment to facilitate cell proliferation, and actively promoting wound healing via a range of mechanisms [45–90]. They can be broadly classified into 1) passive dressings, such as gauze and bandages that stop bleeding, absorb wound exudate, and protect the wound from the external environment; 2) bioactive dressings including hydrogels and films that can be loaded with a range of bioactive agents such as antibiotics and growth factors; and 3) interactive dressings such as foams, sponges, and membranes that act as a barrier against microbes, provide a moist wound environment, and enhance granulation and re-epithelialization [45–90]. The global prevalence of chronic wounds from 2000 to 2018 was approximately 2.21 per 1000 population. Managing wounds imposes significant financial burdens on health systems worldwide, consuming 2–4% of national health expenditures and costing about USD 30,000 per episode in 2015 [45–90]. However, the clinical and financial burden of chronic wounds including high disability-adjusted life years, reduced quality of life, and in severe cases, amputation and death remains vastly underestimated [45–90]. Wound dressings with natural antimicrobial, moisturizing and swelling properties have received increasing attention. However, many natural materials used as wound dressings require chemical cross-linking agents or acidic and alkaline environments and have problems such as poor stability and uneven distribution [45–91].

A chronic wound is a serious complication associated with diabetes mellitus and is difficult to heal due to high glucose levels, oxidative stress, and biofilm-associated microbial infection [45–91]. The structural complexity of microbial biofilm makes it impossible for antibiotics to penetrate the matrix, hence conventional antibiotic therapies became ineffective in clinical settings [45–91]. This demonstrates an urgent need to find safer alternatives to reduce the prevalence of chronic wound infection associated with microbial biofilm [45–91]. A novel approach to address these concerns is to inhibit biofilm formation using biological-macromolecule based nano-delivery system. Higher drug loading efficiency, sustained drug release, enhanced drug stability, and improved bioavailability are advantages of employing nano-drug delivery systems to prevent microbial colonization and biofilm formation in chronic wounds [45–91].

Making use of wound dressings to protect the injured skin can prevent further infection, reduce pain and promote wound healing [45–91]. An ideal wound dressing needs to possess several characteristics, including excellent biocompatible and nontoxic, sufficient antibacterial activity to prevent wound infection good moisturizing properties to promote cell and tissue regeneration, appropriate mechanical strength to ensure its integrity, and good swelling to absorb tissue infiltration fluid [45–91]. Aerogels have a highly porous mesh, pores of controllable size, adjustable surface characteristics, and they have capability to absorb blood exudate as wound dressings [45–91]. In addition, aerogels can quickly capture bacteria and effectively treat bacterial wound infection Therefore aerogels have shown prospects in the field of wound dressings [45–91]. In the last decades, natural polysaccharides such as collagen, chitin, chitosan, and cellulose have been considered as high-quality candidates for wound dressings [45–91]. Collagen chitosan, and alginate are very absorbent and can absorb wound exudate to provide a moist healing environment [45–91]. However, they need to be modified with chemical cross-linkers or non-degradable polymeric materials to increase its mechanical strength, which may affect its biological properties. In comparison to these, cellulose have promising application as wound dressings due to their physical and chemical properties [45–91]. Currently, many studies focus on applying cellulose (in the dressing, and carboxymethylcellulose wound dressings can absorb wound exudate, however, the methods of carboxymethylation and cross-linking cannot completely improve the capacity of the absorption [45–91].

On the basis of literature survey, research suggested that cannabidiol (CBD) and cannabis-based therapies may protect against oxidative stress, potentially reducing inflammation and cell damage in the chronic wound microenvironment and the surrounding tissues [54-92]. Cannabidiol is the non-psychoactive compound found in the *Cannabis sativa* (L.) plant, known for its significant anti-inflammatory properties and its ability to promote wound healing [54-92]. Cannabis oil is rich in carotenoids, including flavonoids, terpenes, chlorophylls, and phytosterols, and is a source of β-carotene, lutein, and zeaxanthin [54-93]. These carotenoids have antioxidant properties that scavenge free radicals and protect against UV light [54-92]. They also enhance skin moisturization, aid in wound healing, and stimulate the synthesis of collagen and elastin by activating fibroblasts [54–90]. *β*-carotene can inhibit the activation of pro-inflammatory cytokines caused by ultraviolet B (UV-B) light, demonstrating anti-inflammatory properties [54–90]. Chlorophyll, a naturally occurring compound in cannabis oil, stimulates tissue development and has antimicrobial qualities, making it effective in treating wounds and skin conditions such as acne, eczema, and ulcers [54–92]. Chlorophyll is also responsible for the green color of hemp seed oil [54–92]. The presence of flavonoids, terpenes, carotenoids, chlorophylls, and phytosterols in cannabis seed oil contributes to its anti-inflammatory and anti-aging effects [54–90]. The oil has a high absorption rate and does not clog pores, making it valuable for skin-soothing formulations including sunscreen, creams, and lotions [54–90]. Topical lotions and ointments based on cannabis oil show promise in anti-aging skincare [54–90]. Early findings suggest that bioactive compounds e.g., asiatic acid, quercetin, curcumin, myricetin, calophyllolide, lupeol, catechin, gallic acid, resveratrol, and naringenin may offer significant benefits by enhancing various aspects of the wound-healing process [54–90-94].

On the basis of literature survey [54–92], cannabis oil stands out in the realm of wound care due to its unique combination of antimicrobial, anti-inflammatory, and antioxidant properties [54–90]. The traditional antiseptics and disinfectants, while effective at eliminating pathogens, can sometimes cause tissue irritation and do not address the oxidative stress caused by ROS [54–92]. In contrast, cannabis oil provides a gentler antimicrobial effect without the harsh side effects, while also mitigating the oxidative damage caused by ROS through its antioxidant properties [54–90]. Various antibiotics are crucial for treating bacterial infections in wounds but carry the risk of resistance and allergic reactions [54–90]. Cannabis oil, with its natural antimicrobial components like CBD and THC, offers an alternative that reduces these risks while also delivering anti-inflammatory benefits [54–92]. Additionally, anti-inflammatory medications, such as NSAIDs and corticosteroids, effectively reduce inflammation and pain but can have systemic side effects with prolonged use [54–92]. Cannabis oil offers a holistic approach to managing inflammation, minimizing systemic exposure, and promoting overall skin health and regeneration [54–90]. Wound dressings are essential for maintaining a moist environment and protecting the wound; however, they can benefit from the addition of cannabis oil, which can enhance their effectiveness by providing added anti-inflammatory and antimicrobial support [54–92].

Cannabis oil, especially its primary bioactive constituents, CBD and THC, demonstrates considerable potential in facilitating skin wound healing by modifying oxidative stress via the regulation of reactive oxygen species [54–90]. CBD's therapeutic effects in wound healing are largely attributed to its antioxidant, anti-inflammatory, and antimicrobial properties [54–90]. Increased ROS levels can hinder wound healing by exacerbating inflammation and cellular damage; however, CBD's antioxidant properties mitigate these effects, fostering a more conducive environment for tissue regeneration [54–90]. Additionally, the antibacterial and analgesic properties of cannabis contribute to reducing the microbial load and minimizing the complications associated with chronic wounds, thereby enhancing the overall healing efficacy [54–90]. Integrating cannabis oil into drug delivery systems for wound management represents a promising strategy for treating both acute and chronic wounds [54–92]. However, further clinical research is needed to fully understand the mechanisms involved and to optimize the therapeutic applications of cannabis oil in wound care [54–90-92].

Cannabinoids possess various therapeutic properties, including appetite stimulation, antioxidant, analgesic, angiogenic, anti-inflammatory, and skin moisturizing effects, all beneficial for wound healing [54–90]. Additionally, cannabinoids regulate the reactive oxygen species production during wound healing, with tetrahydrocannabinol (THC) and cannabidiol (CBD) exhibiting antioxidant activity comparable to that of vitamins C and E [54–90]. Cannabinoids promote chronic wound healing by regulating keratinocyte proliferation and differentiation at the wound edge, modulating matrix metalloproteinases (MMPs), reducing pro-inflammatory cytokines, shifting macrophage responses from a pro-inflammatory M1 to an anti-inflammatory M2 profile, and reducing nitric oxide signalling at the wound bed [54–90]. Activation of CB2R decreases the expression of collagen I and III, MMP-1, and MMP-3, while increasing the expression of the tissue inhibitor of metalloprotease-1 (TIMP-1), MMP-2, and MMP-9 [54–90]. CB1R and CB2R agonists also inhibit the release of sulfated glycosaminoglycans [54–90]. In acute wound healing, CB2R modulation accelerates wound closure and regulates fibrogenesis, potentially minimizing scarring [54–90-92].

Cannabis and its various derivatives are commonly used for both recreational and medicinal purposes [1-54–90-94]. Cannabinoids have been shown to have anti‐inflammatory properties [1-54–90]. Inflammation is an important component of wound healing and the effect of cannabinoids on wound healing has become a recent topic of investigation. Cannabinoids appear to improve skin wound healing through a variety of mechanisms [1-54–90]. This is supported through a variety of in vitro and animal studies. Animal studies suggest application of cannabinoids may improve the healing of postsurgical and chronic wounds [1-54–90]. There are few human studies which evaluate the effects of cannabinoids on wound healing and many of these are case series and observational studies [54–90].

They do suggest cannabinoids may have some benefit. However, definitive conclusions cannot be drawn from them [54–90]. While the systemic effects of cannabis have been well studied, there is a dearth of literature addressing the effects on the wound healing process [54–90]. Cannabis and its components have been shown to have anti‐inflammatory properties. As inflammation is an important component within the process of wound healing, the effect of cannabis and its constituents on wound healing has become a topic of renewed investigation [54–90].

In vitro studies have offered a variety of targets in which cannabis containing compounds may influence wound healing [54–90]. Overall, these studies suggest a positive effect on wound healing by cannabinoids [54–90]. One study even utilized human skin samples and noted hypertrophic scars had lower levels of anandamide when compared to those with normal scars [54–90]. Perhaps the most compelling of target based on these studies is CB2 and its modulation of the acute phase inflammatory response [54–90]. Although the available human studies addressing cannabinoids and skin wound healing have promising results, the relative paucity of more robust study methods (e.g., randomized control trials, prospective case - control studies, etc.) limits their applicability [54–90].

However, topical medications have a risk of acute skin reactions such as contact dermatitis or urticaria and this would also be a concern for topical cannabinoids [54–90]. Interestingly, the endocannabinoid system may attenuate contact dermatitis and play a protective in these reactions [54–90]. A recent study evaluated the dermatological side effects of topical cannabinoids, including CBD and hemp seed oil [54–90]. Overall, they found no significant reactions via patch testing and only saw a mild phototoxicity at 48 h when treated with hemp seed oil [54–90]. The findings suggest that these products appear to be safe [54–90]. However, given the various formulations that are in the market and the difficulty in regulating topical cannabinoids, these results are likely not generalizable to all cannabinoid products [54–90]. Further research is needed to understand the full spectrum of side effects of topical cannabinoids [54–90]. Topical and local application can be performed by several methods including oils, ointment, paste, local injection after wound closure, or impregnation into dressings [54–90]. Additionally, some formulations may allow for sustained drug delivery. For example, Zhao et al. developed a hydrogel which required only one application [54–90]. If further human studies do show improved wound healing after cannabinoid application, optimizing drug delivery methods will be critical to improved outcomes [54–90].

Morguette et al., (2023) [91] reported that wounds of an acute or chronic etiology affect millions of people worldwide, with increasing prevalence every year [91]. Microbial infections are one of the main causes that impair the wound healing process, and *Staphylococcus aureus*, a commensal member of the skin microbiota, is one of the main causative agents of wound infections [91]. Crucially, a high proportion of these infections are caused by methicillin-resistant Staphylococcus aureus, which, in addition to β-lactams, has acquired resistance to almost all the antibacterial agents used to treat it, limiting therapeutic options [91]. Studies on the antimicrobial and healing activities of extracts, essential oils, or metabolites obtained from native plants have been reported in many countries that have a diverse flora and traditions with the use of medicinal plants for the treatment of wound infections [91]. Due to their great chemical diversity, plants have proven to be promising sources of bioactive molecules for the discovery and development of new drugs or strategies for the treatment of wounds [91].

Cannabinoids appear to improve cutaneous wound healing through a variety of mechanisms, most notably through the CB2 receptor [54–90]. Additional, more robust, in vivo and human studies are needed to better define these mechanisms as well as examine cannabinoid's role in human cutaneous wound healing [54–90]. Finally, while the risks of systemic cannabinoids are well described, the risks of topical cannabinoids are not well known [54–90]. Although their side effects do appear to be relatively mild, further studies are needed to understand the adverse effects of topical cannabinoids [54–90].

Cannabis Sativa L. (*Cannabaceae*) exerts biological effects through its bioactive compounds. *Cannabis Sativa* L. essential oil (CSEO) is known to have antibacterial properties that can accelerate wound healing [54–90]. One of the study by Sanae El Ghacham et al., (2023) [85] aimed to evaluate the wound healing efficacy of freshly extracted essential oils from *Cannabis Sativa* L. hydro-distillated from the leaves of the plant [85]. CSEO was analyzed by gas chromatography-mass spectrometry [85]. CSEO demonstrated anti-inflammatory activity by reducing neutrophil levels in blood and skin tissue [85]. CSEO acts by accelerating re-epithelialization and granulation tissue formation [85]. Furthermore, CSEO restored incision-induced neurobehavioral changes by reducing cortisol levels [85]. Increased cortisol levels are associated with inhibition of the healing process, anxiolytic effects, and increased vertical loco motor activity in treated animals [85]. The effect of CSEO in the healing process makes it worthy of recommendation as a therapeutic agent for the treatment of skin wounds [85].

According to the literature survey [54–91], the evidence on the wound healing and antibacterial properties of medicinal cannabis (MC) in treating integument wounds and infections, whether used alone or in combination with other agents has been reported [54–91]. The findings demonstrated that MC possesses significant antibacterial properties and promotes wound healing, showing promising results in both animal models and human studies [54–91]. Hemp fruit oil extract, CBD, and GP1a resulted in complete healing in acute wounds in 23 (5–84) days with a 66–86% healing rate in 10 days in animal models. CBD and tetrahydrocannabidiol irradicated Staphylococcus aureus and MRSA in skin infections of animal models [54–91]. MC oils quantified for THC and CBD content, CBD-rich oil, and gels with THC, CBD, and terpenes promoted healing of chronic, non-healing wounds in humans with complete wound closure in 54 (21–150) days [54–91]. In human subjects, the use of cannabinoids led to reduced blistering, shortened healing times, and alleviated symptoms, thus improving quality of life through topical, oral, and sublingual routes [54–91]. The observed side effects were minimal, with increased appetite from sublingual oil in humans and increases in white blood cell count by CBD in animals being the most common [54–91]. However, the absence of controlled clinical trials and the inconsistent reporting of outcomes across studies significantly limit our ability to draw definitive conclusions regarding the specific effects of cannabinoids on different wound healing phases. Therefore, further robust, controlled studies are necessary to fully understand the therapeutic potential of cannabinoids in treating superficial bacterial skin and skin structure infections as well as dermal wounds [54–91].

Hemp-based materials are regarded as important components of wound dressings [54–91]. Hemp is considered a botanical class of "*Cannabis sativa*", and it has been used in various applications, including paper, textiles, biodegradable plastic, and animal feed, as well as for medicinal use [54–91-95]. Cellulose has many outstanding properties, including a very large surface area-to-volume ratio, good mechanical properties, and a very low coefficient of thermal expansion [54–91]. In order to employ cellulose derived from hemp with higher efficiency, cellulose-based composite materials were developed. Hydrogel composite prepared from bio-based materials is therefore considered as a promising route. Besides their eco-friendly nature, their ease of degradation as well as their non-toxicity are interesting attributes [54–91]. Besides their eco-friendly nature, their ease of degradation as well as their non-toxicity are interesting attributes [54–91]. Hydrogel is considered as one of the most effective materials for medical uses. Hydrogel is typically defined as a three-dimensional polymeric network containing chemically or physically crosslinked hydrophilic polymer chains [54–91]. It can also retain a large amount of water [54–91]. Due to the presence of hydrophilic groups, it can be employed to absorb wound exudates and allow oxygen transportation in order to accelerate the wound healing process [54–91]. Moreover, it can be designed based on a biocompatible concept in order to prevent bacterial infection and maintain moisture content, as well as support the adhesion to tissue [54–91]. Currently, the use of hydrogel provides various advantages for medical research, including the encouragement of an appropriate microenvironment for cell growth and the recruitment of fibroblasts, as well as the proliferation process [54–91]. The hydrogels were evaluated for their skin wound healing efficacy and parameters such as antimicrobial properties, adhesion, and hemostasis, as well as anti-inflammatory properties, were investigated [54–91].

In one of the study reported by Promdontree et al., (2023) [86] cellulose nanocrystals (CNCs) were successfully extracted and purified from hemp using an alkaline treatment and bleaching process and subsequently used in conjunction with polyvinyl alcohol to form a composite hydrogel [86]. Cellulose nanocrystals (1–10% (w/v)) were integrated into polyvinyl alcohol, and sodium tetraborate (borax) was employed as a crosslinking agent [86]. Due to the small number of cellulose nanocrystals, no significant peak change was observed in the FT-IR spectra compared to pristine polyvinyl alcohol [86]. The porosity was created upon the removal of the water molecules, and the material was thermally stable up to 200^{o} C [86]. With the presence of cellulose nanocrystals, the melting temperature was slightly shifted to a higher temperature, while the glass transition temperature remained practically unchanged. The swelling behavior was examined for 180 min in deionized water and PBS solution (pH 7.4) at 37 ^{o}C [86]. The degree of swelling of the composite with cellulose nanocrystals was found to be higher than that of pristine PVA hydrogel [86]. The cell viability (%) of the prepared hydrogel with different proportions of cellulose nanocrystals was higher than that of pristine PVA hydrogel [86]. Based on the results, the prepared composite hydrogels from cellulose nanocrystals extracted from hemp and polyvinyl alcohol were revealed to be an excellent candidate for scaffold material for medical usage [86]. Furthermore, the cellulose nanocrystals slightly enhanced the thermal stability of the composite hydrogel [86].

In one of the study reported by Chelminiak-Dudkiewicz et al., (2022) [89] a novel chitosan-based biomaterials containing cannabis oil to potentially promote wound healing [89]. The primary active substance in cannabis oil is the non-psychoactive cannabidiol, which has many beneficial properties [89]. In this study, three chitosan based films containing different concentrations of cannabis oil were prepared [89]. As the amount of oil increased, the obtained biomaterials became rougher as tested by atomic force microscopy [89]. Such rough surfaces promote protein adsorption, confirmed by experiments assessing the interaction between human albumin with the obtained materials [89]. Increased oil concentration also improved the films' mechanical parameters, swelling capacity, and hydrophilic properties, which were checked by the wetting angle measurement [89]. On the other hand, higher oil content resulted in decreased water vapour permeability, which is essential in wound dressing [89]. Furthermore, the prepared films were subjected to an acute toxicity test using a Microtox. Significantly, the film's increased cannabis oil content enhanced the antimicrobial effect against *A. fischeri* for films in direct contact with bacteria [89]. More importantly, cell culture studies revealed that the obtained materials are biocompatible and, therefore, they might be potential candidates for application in wound dressing materials [89].

Cannabidiol (CBD) can come in various formulations (capsules, chewing gums, sprays). However, the most interesting product seems to be cannabis oil, which contains CBD mixed with a base (carrier) oil such as coconut oil or cannabis seed oil [54–91]. CBD oil also contains a wide variety of fatty acids, proteins, amino acids, vitamins A, C, and E, β-carotene, and minerals, specifically phosphorus, potassium, magnesium, sulfur, and calcium [54–91]. Owing to these, CBD oil can be used as a remedy for skin lesions. Moreover, unsaturated fatty acids accelerate wound healing processes and reduce inflammation. Cannabis oil is also readily available, which is an additional advantage [54–91]. In this study, reported by Chelminiak-Dudkiewicz et al., (2022) [89], novel chitosan-based biomaterials containing cannabidiol were obtained, with cannabis oil being used as a source of cannabidiol [89]. A complete characterization of the prepared films, including surface morphology, chemical structure, thermal stability, mechanical properties, and CBD release, was carried out [89]. The extent of protein adsorption (human serum albumin) on the surface of the obtained biomaterials was evaluated. Furthermore, the preliminary acute toxicity of the prepared samples was studied using the Microtox test. The results suggest that the cannabidiol-containing chitosan-based films (CBD-CS) possess the most prerequisites for a good dressing for wound healing applications [89]. Moreover, cannabidiol is lipophilic and is easily absorbed into all types of cutaneous wounds, and of equal importance is the fact that CBD can reduce the production of reactive oxygen species, which is essential to promote wound healing. Some biopolymers such as chitosan, cellulose, collagen, alginate, and keratin have been studied as dressing materials, e.g., films, foams, and hydrogels [89]. Many natural active substances reveal antibacterial properties and might have potential use in treating wound infections. Recent studies have reported using various natural agents for wound healing, such as honey, aloe vera, quercetin, thymol, and curcumin has been reported [89].

According to the study reported by Chelminiak-Dudkiewicz et al., (2022) [89] developing novel biomaterials for wound dressing applications using natural polymers and active substances with antimicrobial properties is beneficial for wound treatment. Cannabis oil is rich in many active compounds, and its main component—cannabidiol, provides antimicrobial, antioxidant, regenerative, and antithrombotic properties of beneficial properties for wound treatment [89]. According to the study reported by Chelminiak-Dudkiewicz et al., (2022) [89] all chitosan-based film samples with cannabis oil exhibited good mechanical and hydrophilic properties and a high swelling ratio [89]. Degradability tests showed that the films lost their maximum weight within eight days. Moreover, increased concentration of cannabis oil in the samples promoted adsorption of human albumin [89]. The obtained biomaterials showed good antimicrobial activity against *A. fischeri* and a good drug release profile [89]. In addition, cell culture studies demonstrated that designed CBD-CS biomaterials are biocompatible [89]. Therefore, chitosan-based films incorporating cannabis oil might be an excellent candidate for wound treatment and dressing [89].

Very recently the findings of the study conducted by Niyangoda et al., (2024) [56] demonstrated that medical cannabis (MC) possesses significant antibacterial properties and promoted wound healing, showing promising results in both animal models and human studies [56]. Hemp fruit oil extract, CBD, and GP1a resulted in complete healing in acute wounds in 23 (5–84) days with a 66–86% healing rate in 10 days in animal models. CBD and tetrahydrocannabidiol irradicated Staphylococcus aureus and MRSA in skin infections of animal models [56]. MC oils quantified for THC and CBD content, CBD-rich oil, and gels with THC, CBD, and terpenes promoted healing of chronic, non-healing wounds in humans with complete wound closure in 54 (21–150) days [56]. In human subjects, the use of cannabinoids led to reduced blistering, shortened healing times, and alleviated symptoms, thus improving quality of life through topical, oral, and sublingual routes [56]. The observed side effects were minimal, with increased appetite from sublingual oil in humans and increases in white blood cell count by CBD in animals being the most common [56]. However, the absence of controlled clinical trials and the inconsistent reporting of outcomes across studies significantly limit our ability to draw definitive conclusions regarding the specific effects of cannabinoids on different wound healing phases [56]. Therefore, further robust, controlled studies are necessary to fully understand the therapeutic potential of cannabinoids in treating superficial bacterial skin and skin structure infections as well as dermal wounds [56]. The studies examined the effects of various cannabinoid formulations, including combinations with other plant extracts, crude extracts, and purified and synthetic cannabis-based medications administered topically, intraperitoneally, orally, or sublingually [56]. Four animal and three human studies reported complete wound closure. Hemp fruit oil extract, cannabidiol (CBD), and GP1a resulted in complete wound closure in twenty-three (range: 5–84) days with a healing rate of 66–86% within ten days in animal studies [56]. One human study documented a wound healing rate of 3.3 cm^2 over 30 days, while three studies on chronic, non-healing wounds reported an average healing time of 54 (21–150) days for 17 patients by oral oils with Λ9- tetrahydrocannabinol (THC) and CBD and topical gels with THC, CBD, and terpenes. CBD and Λ9-tetrahydrocannabidiol demonstrated significant potential in reducing bacterial loads in murine models [56]. However, further high-quality research is imperative to fully elucidate the therapeutic potential of cannabinoids in the treatment of bacterial skin infections and wounds [56]. Evidence suggests that cannabinoids modulate key molecular pathways of wound healing through CB1R agonism, CB2R agonism/antagonism, or by acting on receptors such as TRPA1, PPARγ, and GPR55[56]. Cannabinoids promote chronic wound healing by regulating keratinocyte proliferation and differentiation at the wound edge, modulating matrix metalloproteinases (MMPs), reducing pro-inflammatory cytokines, shifting macrophage responses from a pro-inflammatory M1 to an anti-inflammatory M2 profile, and reducing nitric oxide signalling at the wound bed [56]. Cannabinoids possess various therapeutic properties, including appetite stimulation, antioxidant, analgesic, angiogenic, anti-inflammatory, and skin moisturizing effects, all beneficial for wound healing. Additionally, cannabinoids regulate the reactive oxygen species production during wound healing, with tetrahydrocannabinol (THC) and cannabidiol (CBD) exhibiting antioxidant activity comparable to that of vitamins C and E [56].

One of the studies by Niyangoda ·et al., (2024) [56] examined the effects of various cannabinoid formulations, including combinations with other plant extracts, crude extracts, and purified and synthetic cannabis-based medications administered topically, intraperitoneally, orally, or sublingually [56]. Four animal and three human studies reported complete wound closure [56]. Hemp fruit oil extract, cannabidiol (CBD), and GP1a resulted in complete wound closure in twenty-three (range: 5–84) days with a healing rate of 66–86% within ten days in animal studies [56]. One human study documented a wound healing rate of 3.3 cm^2 over 30 days, while three studies on chronic, non-healing wounds reported an average healing time of 54 (21–150) days for 17 patients by oral oils with tetrahydrocannabinol (THC) and CBD and topical gels with THC, CBD, and terpenes [56]. CBD and tetrahydrocannabidiol demonstrated significant potential in reducing bacterial loads in murine models [56]. However, further high-quality research is imperative to fully elucidate the therapeutic potential of cannabinoids in the treatment of bacterial skin infections and wounds [54–90]. Additionally, it is crucial to delineate the impact of medicinal cannabis on the various phases of wound healing. This study was registered in PROSPERO (CRD42021255413) [56].

4. Conclusion

Wound healing is a complex biological process involving four sequential and overlapping phases, haemostasis, inflammation, proliferation, and remodeling, which are mediated by various cellular and molecular events to restore tissue integrity. On the basis of literature survey, Cannabis oil, recognized for its antioxidant properties, may help to mitigate oxidative damage by scavenging ROS and upregulating antioxidative mechanisms, potentially enhancing wound healing. Wound healing involves inflammation, angiogenesis, and the formation of granulation tissue. These processes are closely linked to upregulations in OS and ROS levels. ROS are crucial in all the stages of wound healing. Low levels of ROS are essential for combating invading microbes and activating cell survival signaling. Cannabis oil, especially its primary bioactive constituents, CBD and THC, demonstrates considerable potential in facilitating skin wound healing by modifying oxidative stress via the regulation of reactive oxygen species.

However, the clinical and financial burden of chronic wounds—including high disability-adjusted life years, reduced quality of life, and in severe cases, amputation and death—remains vastly underestimated. Medical Cannabis (MC) has a unique advantage in wound healing through its action on the endocannabinoid system (ECS), the body's most extensive neurotransmitter system. Some reviews have summarized molecular mechanisms of wound healing, ex vivo, animal models, and human wound healing by cannabinoids with varying levels of detail. Others have elaborated on the effects of CBD in wound healing. Some of the studies reported that Medical Cannabis (MC) has shown promise for chronic, non-healing wounds resulting from various conditions in humans, the heterogeneity of wound types and outcomes prevented a pooled analysis. However, the absence of controlled clinical trials and the inconsistent reporting of outcomes across studies significantly limit ability to draw definitive conclusions regarding the specific effects of cannabinoids on different wound healing phases.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Malabadi RB, Kolkar KP, Chalannavar RK. *Cannabis sativa*: Ethnobotany and Phytochemistry. International Journal of Innovation Scientific Research and Review. 2023; 5(2): 3990-3998.

[2] Malabadi RB, Kolkar KP, Chalannavar RK. *Cannabis sativa*: Industrial hemp (fiber type)- An *Ayurvedic* traditional herbal medicine. International Journal of Innovation Scientific Research and Review 2023; 5 (2): 4040-4046.

[3] Malabadi RB, Kolkar KP, Achary M, Chalannavar RK. *Cannabis sativa*: Medicinal plant with 1000 Molecules of Pharmaceutical Interest. International Journal of Innovation Scientific Research and Review. 2023; 5(2): 3999-4005.

[4] Malabadi RB, Kolkar KP, Chalannavar RK. Medical *Cannabis sativa* (Marijuana or Drug type); The story of discovery of Δ9-Tetrahydrocannabinol (THC). International Journal of Innovation Scientific Research and Review. 2023; 5 (3):4134-4143.

[5] Malabadi RB, Kolkar KP, Chalannavar RK. Δ9-Tetrahydrocannabinol (THC): The major Psychoactive Component is of Botanical origin. International Journal of Innovation Scientific Research and Review. 2023; 5(3): 4177-4184.

[6] Malabadi RB, Kolkar KP, Chalannavar RK, Lavanya L, Abdi G. *Cannabis sativa*: Botany, Cross Pollination and Plant Breeding Problems. International Journal of Research and Innovations in Applied Science (IJRIAS). 2023; 8 (4): 174-190.

[7] Malabadi RB, Kolkar KP, Chalannavar RK. *Cannabis sativa*: Industrial Hemp (fibre-type)- An emerging opportunity for India. International Journal of Research and Scientific Innovations (IJRSI). 2023; X (3):01-9.

[8] Malabadi RB, Kolkar KP, Chalannavar RK. Industrial *Cannabis sativa* (Hemp fiber type): Hempcrete-A plant based eco-friendly building construction material. International Journal of Research and Innovations in Applied Sciences (IJRIAS). 2023; 8(3): 67-78.

[9] Malabadi RB, Kolkar KP, Chalannavar RK, Lavanya L, Abdi G. *Cannabis sativa*: The difference between Δ8-THC and Δ9-Tetrahydrocannabinol (THC). International Journal of Innovation Scientific Research and Review. 2023; 5(4): 4315-4318.

[10] Malabadi RB, Kolkar KP, Chalannavar RK, Lavanya L, Abdi G. Hemp Helps Human Health: Role of phytocannabinoids. International Journal of Innovation Scientific Research and Review. 2023; 5 (4): 4340-4349.

[11] Malabadi RB, Kolkar KP, Chalannavar RK, Lavanya L, Abdi G, Baijnath H. *Cannabis* products contamination problem: A major quality issue. International Journal of Innovation Scientific Research and Review. 2023;5(4): 4402-4405.

[12] Malabadi RB, Kolkar KP, Chalannavar RK, Lavanya L, Abdi G. Medical *Cannabis sativa* (Marijuana or drug type): Psychoactive molecule, Δ9-Tetrahydrocannabinol (Δ9-THC). International Journal of Research and Innovations in Applied Science. 2023; 8(4): 236-249.

[13] Malabadi RB, Kolkar KP, Chalannavar RK, Mondal M, Lavanya L, Abdi G, Baijnath H. *Cannabis sativa*: Release of volatile organic compounds (VOCs) affecting air quality. International Journal of Research and Innovations in Applied Science (IJRIAS). 2023; 8(5): 23-35.

[14] Malabadi RB, Nethravathi TL, Kolkar KP, Chalannavar RK, Mudigoudra BS, Lavanya L, Abdi G, Baijnath H. *Cannabis sativa*: Applications of Artificial Intelligence and Plant Tissue Culture for Micropropagation. International Journal of Research and Innovations in Applied Science (IJRIAS). 2023; 8(6): 117-142.

[15] Malabadi RB, Nethravathi TL, Kolkar KP, Chalannavar RK, Mudigoudra BS, Abdi G, Baijnath H. *Cannabis sativa*: Applications of Artificial intelligence (AI) in *Cannabis* industries: In Vitro plant tissue culture. International Journal of Research and Innovations in Applied Science (IJRIAS). 2023; 8 (7): 21-40. International Journal of Science and Research Archive. 2023; 10(02): 860–873.

[16] Malabadi RB, Kolkar KP, Brindha C, Chalannavar RK, Abdi G, Baijnath H, Munhoz ANR, Mudigoudra BS. *Cannabis sativa*: Autoflowering and Hybrid Strains. International Journal of Innovation Scientific Research and Review. 2023; 5(7): 4874-4877.

[17] Malabadi RB, Kolkar KP, Chalannavar RK, Munhoz ANR, Abdi G, Baijnath H. *Cannabis sativa*: Dioecious into Monoecious Plants influencing Sex Determination. International Journal of Research and Innovations in Applied Science (IJRIAS). 2023; 8(7): 82-91.

[18] Malabadi RB, Kolkar KP, Chalannavar RK, Baijnath H. *Cannabis sativa*: Difference between Medical Cannabis (marijuana or drug) and Industrial hemp. GSC Biological and Pharmaceutical Sciences. 2023; 24(03):377–81.

[19] Malabadi RB, Kolkar KP, Chalannavar RK, Abdi G, Munhoz ANR, Baijnath H *Cannabis sativa*: Dengue viral disease-Vector control measures. International Journal of Innovation Scientific Research and Review. 2023; 5(8): 5013-5016.

[20] Malabadi RB, Nethravathi TL, Kolkar KP, Chalannavar RK, Mudigoudra BS, Abdi G, Munhoz ANR, Baijnath H. *Cannabis sativa*: One-Plant-One-Medicine for many diseases-Therapeutic Applications. International Journal of Research and Innovations in Applied Science (IJRIAS). 2023; 8(8): 132-174.

[21] Malabadi RB, Nethravathi TL, Kolkar KP, Chalannavar RK, Mudigoudra BS, Abdi G, Munhoz ANR, Baijnath H. Fungal Infection Diseases- Nightmare for Cannabis Industries: Artificial Intelligence Applications International Journal of Research and Innovations in Applied Science (IJRIAS). 2023; 8(8):111-131.

[22] Malabadi RB, Kolkar KP, Chalannavar RK, Acharya M, Mudigoudra BS. *Cannabis sativa*: 2023-Outbreak and Re-emergence of Nipah virus (NiV) in India: Role of Hemp oil. GSC Biological and Pharmaceutical Sciences. 2023; 25(01):063–077.

[23] Malabadi RB, Kolkar KP, Chalannavar RK, Acharya M, Mudigoudra BS. Industrial *Cannabis sativa*: Hemp-Biochar-Applications and Disadvantages. World Journal of Advanced Research and Reviews. 2023; 20(01): 371–383.

[24] Malabadi RB, Kolkar KP, Chalannavar RK, Vassanthini R, Mudigoudra BS. Industrial *Cannabis sativa*: Hemp plastic-Updates. World Journal of Advanced Research and Reviews. 2023; 20 (01): 715-725.

[25] Malabadi RB, Sadiya MR, Kolkar KP, Lavanya L, Chalannavar RK. Quantification of THC levels in different varieties of *Cannabis sativa*. International Journal of Science and Research Archive. 2023; 10(02): 860–873.

[26] Malabadi RB, Sadiya MR, Kolkar KP, Chalannavar RK. Biodiesel production via transesterification reaction. Open Access Research Journal of Science and Technology. 2023; 09(02): 010–021.

[27] Malabadi RB, Sadiya MR, Kolkar KP, Chalannavar RK. Biodiesel production: An updated review of evidence. International Journal of Biological and Pharmaceutical Sciences Archive. 2023; 06(02): 110–133.

[28] Malabadi RB, Kolkar KP, Chalannavar RK. Industrial *Cannabis sativa*: Hemp oil for biodiesel production. Magna Scientia Advanced Research and Reviews. 2023; 09(02): 022–035.

[29] Malabadi RB, Kolkar KP, Chalannavar RK. Industrial *Cannabis sativa*: Role of hemp (fiber type) in textile industries. World Journal of Biology, Pharmacy and Health Sciences. 2023; 16(02): 001–014.

[30] Malabadi RB, Mammadova SS, Kolkar KP, Sadiya MR, Chalannavar RK, Castaño Coronado KV. *Cannabis sativa*: A therapeutic medicinal plant-global marketing updates. World Journal of Biology, Pharmacy and Health Sciences. 2024; 17(02):170–183.

[31] Malabadi RB, Kolkar KP, Sadiya MR, Veena Sharada B, Mammodova SS, Chalannavar RK, Baijnath H, Nalini S, Nandini S, Munhoz ANR. Triple Negative Breast Cancer (TNBC): *Cannabis sativa*-Role of Phytocannabinoids. World Journal of Biology, Pharmacy and Health Sciences. 2024; 17(03): 140–179.

[32] Malabadi RB, Sadiya MR, Kolkar KP, Mammadova SS, Chalannavar RK, Baijnath H. Role of Plant derived-medicine for controlling Cancer. International Journal of Science and Research Archive. 2024; 11(01): 2502–2539.

[33] Malabadi RB, Sadiya MR, Kolkar KP, Mammadova SS, Chalannavar RK, Baijnath H, Lavanya L, Munhoz ANR. Triple Negative Breast Cancer (TNBC): Signalling pathways-Role of plant-based inhibitors. Open Access Research Journal of Biology and Pharmacy, 2024; 10(02), 028–071.

[34] Fernando de C, Lambert C, Barbosa Filh, EV, Castaño Coronado KV, Malabadi RB Exploring the potentialities of industrial hemp for sustainable rural development. World Journal of Biology Pharmacy and Health Sciences. 2024; 18(01): 305–320.

[35] Malabadi RB, Sadiya MR, Prathima TC, Kolkar KP, Mammadova SS, Chalannavar RK. *Cannabis sativa*: Cervical cancer treatment- Role of phytocannabinoids-A story of concern. World Journal of Biology, Pharmacy and Health Sciences. 2024; 17(02): 253–296.

[36] Malabadi RB, Kolkar KP, Chalannavar RK, Baijnath H. *Cannabis sativa*: Monoecious species and Hermaphroditism: Feminized seed production- A breeding effort. World Journal of Biology Pharmacy and Health Sciences. 2024; 20(03): 169-183.

[37] Malabadi RB, Kolkar KP, Chalannavar RK, Baijnath H. *Cannabis sativa*: Extraction Methods for Phytocannabinoids -An Update. World Journal of Biology Pharmacy and Health Sciences. 2024; 20(03): 018–058.

[38] Malabadi RB, Kolkar KP, Chalannavar RK, Baijnath H. *Cannabis sativa*: Polyploidization-Triploid and Tetraploid Production. World Journal of Biology Pharmacy and Health Sciences. 2024; 20(03), 567-587.

[39] Malabadi RB, Kolkar KP, Chalannavar RK, Baijnath H. Plant Based Leather Production-An update. World Journal of Advanced Engineering Technology and Sciences. 2025;14(01): 031-059.

[40] Malabadi RB, Kolkar KP**,** Castaño Coronado KV, Chalannavar RK. *Cannabis sativa*: Quality control testing measures and guidelines: An update. World Journal of Advanced Engineering Technology and Sciences. 2025;14(01): 110-129.

[41] Malabadi RB, Kolkar KP, Chalannavar RK, Munhoz ANR. *In vitro* Anther culture and Production of Haploids in *Cannabis sativa.* Open Access Research Journal of Science and Technology. 2025;13(01): 001-020. (https://doi.org/10.53022/oarjst.2025.13.1.0150).

[42] Malabadi RB, Chalannavar RK, Divakar MS , Swathi , Komalakshi KV, Kamble AA, Karamchand KS, Kolkar KP, Nethravathi TL, Castaño Coronado KV, Munhoz ANR. Industrial *Cannabis sativa* (Fiber or Hemp): 3D printing-hempcrete-a sustainable building material. World Journal of Advanced Engineering Technology and Sciences. 2025;14(02): 253-282.

[43] Chalannavar RK, Malabadi RB, Divakar MS, Swathi, Komalakshi KV, Kamble AA Kishore S. Karamchand KS, Kolkar KP, Castaño Coronado KV, Munhoz ANR. Industrial *Cannabis sativa* (Fiber or Hemp): Hemp made Leather. World Journal of Advanced Research and Reviews. 2025; 25(02): 2207-2218.

[44] Mariz J, Guise C, Silva TL, Rodrigues L, Silva CJ. Hemp: From Field to Fiber—A Review. Textiles. 2024; 4: 165–182. https:// doi.org/10.3390/textiles4020011.

[45] Nasalapure AV, Chalannavar RK, Gani RS, Malabadi RB, Kasai DR. Tissue Engineering of Skin: A Review. Trends Biomater. Artif. Organs. 2017; 31(2): 69-80.

[46] Malabadi RB, Kolkar KP, Acharya M, Nityasree BR, Chalannavar RK. Wound Healing: Role of Traditional Herbal Medicine Treatment. International Journal of Innovation Scientific Research and Review. 2022; 4(6): 2856-2874.

[47] Portela R, Leal CR, Almeida PL, Sobral RG. Bacterial cellulose: A versatile biopolymer for wound dressing applications. Microb Biotechnol. 2019;12(4):586-610. doi: 10.1111/1751-7915.13392.

[48] Naomi R, Bt Hj Idrus R, Fauzi MB. Plant- vs. Bacterial-Derived Cellulose for Wound Healing: A Review. Int J Environ Res Public Health. 2020; 18;17(18):6803. doi: 10.3390/ijerph17186803.

[49] Meiling Zhang, Ningting Guo, Yahu Sun, Jianhao Shao, Qianqian Liu, Xupin Zhuang, Collins Bagiritima Twebaze, Nanocellulose aerogels from banana pseudo-stem as a wound dressing. Industrial Crops and Products. 2023;194: 116383. https://doi.org/10.1016/j.indcrop.2023.116383.

[50] Goswami AG, Basu S, Banerjee T. *et al.* Biofilm and wound healing: from bench to bedside. Eur J Med Res. 2023*;* 28, 157. https://doi.org/10.1186/s40001-023-01121-7.

[51] Opricǎ GM, Panaitescu DM, Lixandru BE, Uşurelu CD, Gabor AR, Nicolae CA, Fierascu RC, Frone AN. Plant-Derived Nanocellulose with Antibacterial Activity for Wound Healing Dressing. Pharmaceutics. 2023; 25;15(12):2672. doi: 10.3390/pharmaceutics15122672.

[52] Kart NB, Sulak M, Mutlu D. *et al.* Evaluation of Anti-Biofilm and in Vitro Wound Healing Activity of Bacterial Cellulose Loaded with Nanoparticles and Borax. J Polym Environ. 2024*;* 32: 5654–5665 https://doi.org/10.1007/s10924-024-03308-3.

[53] Guillamat-Prats R. The Role of MSC in Wound Healing, Scarring and Regeneration. Cells. 2021; 8;10(7):1729. doi: 10.3390/cells10071729.

[54] Israni DK, Raghani NR, Soni J, Shah M, Prajapati BG, Chorawala MR, Mangmool S, Singh S, Chittasupho C. Harnessing *Cannabis sativa* Oil for Enhanced Skin Wound Healing: The Role of Reactive Oxygen Species Regulation. Pharmaceutics. 2024 30;16(10):1277. doi: 10.3390/pharmaceutics16101277.

[55] Parikh AC, Jeffery CS, Sandhu Z, Brownlee BP, Queimado L, Mims MM. The effect of cannabinoids on wound healing: A review. Health Sci Rep. 2024; 25;7(2):e1908. doi: 10.1002/hsr2.1908.

[56] Niyangoda D, Muayad M, Tesfaye W, Bushell M, Ahmad D, Samarawickrema I, Sinclair J, Kebriti S, Maida V, Thomas J. Cannabinoids in Integumentary Wound Care: A Systematic Review of Emerging Preclinical and Clinical Evidence. Pharmaceutics. 2024, 16: 1081. https://doi.org/10.3390/ pharmaceutics16081081

[57] Sorg H, Tilkorn DJ, Hager S, Hauser J, Mirastschijski U. Skin wound healing: an update on the current knowledge and concepts. Eur Surg Res. 2017;58(1‐2):81‐94.

[58] Mackie K. Cannabinoid receptors: where they are and what they do. J Neuroendocrinol. 2008;20(s1):10‐14.

[59] Cohen K, Weinstein A. The effects of cannabinoids on executive functions: evidence from cannabis and synthetic Cannabinoids—a systematic review. Brain Sci. 2018;8(3):40.

[60] El‐Alfy AT, Ivey K, Robinson K, et al. Antidepressant‐like effect of Δ9‐tetrahydrocannabinol and other cannabinoids isolated from *Cannabis sativa* L. Pharmacol Biochem Behav. 2010;95(4): 434‐442.

[61] Russo EB. History of cannabis and its preparations in saga, science, and sobriquet. Chem Biodiversity. 2007;4(8):1614 ‐ 648.

[62] Atalay S, Jarocka ‐ Karpowicz I, Skrzydlewska E. Antioxidative and anti ‐ inflammatory properties of cannabidiol. Antioxidants (Basel, Switzerland). 2019;9(1):21.

[63] Atalay S, Gęgotek A, Domingues P, Skrzydlewska E. Protective effects of cannabidiol on the membrane proteins of skin keratinocytes exposed to hydrogen peroxide via participation in the proteostasis network. Redox Biol. 2021;46:102074.

[64] Antezana PE, Municoy S, Pérez CJ, Desimone MF. Collagen hydrogels loaded with silver nanoparticles and Cannabis sativa oil. Antibiotics. 2021;10(11):1420.

[65] Zheng JL, Yu TS, Li XN, et al. Cannabinoid receptor type 2 is time ‐ dependently expressed during skin wound healing in mice. Int J Legal Med. 2012;126(5):807 ‐ 814

[66] Correia ‐ Sá I, Paiva A, Carvalho CM, Vieira ‐ Coelho MA. Cutaneous endocannabinoid system: does it have a role on skin wound healing bearing fibrosis? Pharmacol Res. 2020;159:104862.

[67] Sorg H, Tilkorn DJ, Hager S, Hauser J, Mirastschijski U. Skin wound healing: An update on the current knowledge and concepts. Eur Surg Res. 2017;58(1 ‐ 2):81 ‐ 94.

[68] Sangiovanni E, Fumagalli M, Pacchetti B, et al. Cannabis sativa L. extract and cannabidiol inhibit in vitro mediators of skin inflammation and wound injury. Phytother Res. 2019;33(8): 2083 ‐ 2093. Available from: https://onlinelibrary.wiley.com/ doi/10.1002/ptr.6400.

[69] Li SS, Wang LL, Liu M, et al. Cannabinoid CB2 receptors are involved in the regulation of fibrogenesis during skin wound repair in mice. Mol Med Rep. 2016;13(4):3441 ‐ 3450.

[70] Klein M, de Quadros De Bortolli J, Guimarães FS, Salum FG, Cherubini K, de Figueiredo MAZ. Effects of cannabidiol, a *Cannabis sativa* constituent, on oral wound healing process in rats: clinical and histological evaluation. Phytother Res. 2018; 32(11):2275 ‐ 2281.

[71] Koyama S, Purk A, Kaur M, et al. Beta ‐ caryophyllene enhances wound healing through multiple routes. PloS one. 2019;14(12): e0216104

[72] Karsak M, Gaffal E, Date R, et al. Attenuation of allergic contact dermatitis through the endocannabinoid system. Science. 2007; 316(5830):1494 ‐ 1497.

[73] Maghfour J, Rietcheck H, Szeto MD, et al. Tolerability profile of topical cannabidiol and palmitoylethanolamide: a compilation of single ‐ centre randomized evaluator ‐ blinded clinical and in vitro studies in normal skin. Clin Exp Dermatol. 2021;46(8):1518 ‐ 1529.

[74] CorreiaSá I, Carvalho C, Machado V, et al. Targeting cannabinoid receptor 2 (CB2) limits collagen production—an in vitro study in a primary culture of human fibroblasts. Fundam Clin Pharmacol. 2022; 36(1):89 ‐ 99.

[75] Ruhl T, Lippold EF, Christer T, Schaefer B, Kim BS, Beier JP. Genetic deletion of the cannabinoid receptors CB1 and CB2 enhances inflammation with diverging effects on skin wound healing in mice. Life Sci. 2021;285:120018.

[76] Palmieri B, Laurino C, Vadalà M. A therapeutic effect of CBD ‐ enriched ointment in inflammatory skin diseases and cutaneous scars. Clin Ter. 2019;170(2):e93e99.

[77] Maida V, Shi RB, Fazzari FGT, Zomparelli L. Topical cannabis ‐ based medicines—a novel paradigm and treatment for non ‐ uremic calciphylaxis leg ulcers: an open label trial. Int Wound J. 2020;17(5): 1508 ‐ 1516.

[78] Diaz P, Katz T, Langleben A, Rabinovitch B, Lewis E. Healing of a chronic pressure injury in a patient treated with medical cannabis for pain and sleep improvement: a case report. Wound Manag Prev. 2021;67(10):42 ‐ 47.

[79] Schräder NHB, Gorell ES, Stewart RE, et al. Cannabinoid use and effects in patients with epidermolysis bullosa: an international cross ‐ sectional survey study. Orphanet J Rare Dis. 2021; 16(1):377

[80] McIver V, Tsang A, Symonds N, et al. Effects of topical treatment of cannabidiol extract in a unique manuka factor 5 manuka honey carrier on second intention wound healing on equine distal limb wounds: a preliminary study. Aust Vet J. 2020;98(6):250 ‐ 255

[81] Du Y, Ren P, Wang Q, et al. Cannabinoid 2 receptor attenuates inflammation during skin wound healing by inhibiting M1 macrophages rather than activating M2 macrophages. J. Inflamm (Lond). 2018;15(1):25.

[82] Wohlman IM, Composto GM, Heck DE, et al. Mustard vesicants alter expression of the endocannabinoid system in mouse skin. Toxicol Appl Pharmacol. 2016;303:30 ‐ 44.

[83] Maida V, Shi RB, Fazzari FGT, Zomparelli L. Topical cannabis ‐ based medicines—a novel adjuvant treatment for venous leg ulcers: an open ‐ label trial. Exp Dermatol. 2021;30(9):1258 ‐ 1267.

[84] Wang LL, Zhao R, Li JY, et al. Pharmacological activation of cannabinoid 2 receptor attenuates inflammation, fibrogenesis, and promotes re ‐ epithelialization during skin wound healing. Eur J Pharmacol. 2016;786:128 ‐ 136.

[85] Sanae El Ghacham, Ismail El Bakali, Mohamed Amine Zarouki, Youssef Aoulad El Hadj Ali, Rachid Ismaili, Amina El Ayadi, Badredine Souhail, Lahcen Tamegart, Abdelmonaim Azzouz. Wound healing efficacy of *Cannabis sativa* L. essential oil in a mouse incisional wound model: A possible link with stress and anxiety. South African Journal of Botany. 2023; 163: 488-496. https://doi.org/10.1016/j.sajb.2023.11.005.

[86] Promdontree P, Kheolamai P, Ounkaew A, Narain R, Ummartyotin S. Characterization of Cellulose Fiber Derived from Hemp and Polyvinyl Alcohol-Based Composite Hydrogel as a Scaffold Material. Polymers. 2023; 15: 4098. https://doi.org/10.3390/ polym15204098.

[87] Liang Y, He J, Guo B. Functional Hydrogels as Wound Dressing to Enhance Wound Healing. ACS Nano 2021; 15: 12687–12722.

[88] Thi-Phuong Ho T. et al. Natural Polymer-Based Materials for Wound Healing Applications. Adv. NanoBiomed Res.. 2024; 4: 2300131.

[89] Chelminiak-Dudkiewicz D, Smolarkiewicz-Wyczachowski A et al., Chitosan-based films with cannabis oil as a base material for wound dressing application. Scientific Reports. 2022; 12:18658. https://doi.org/10.1038/s41598-022-23506-0.

[90] Singh S, Young A, McNaught CE. The physiology of wound healing. Surgery. 2017; 35, 473–477.

[91] Morguette AEB, Bartolomeu-Gonçalves G, Andriani GM, Bertoncini GES, Castro IM, Spoladori LFA, Bertão AMS, Tavares ER, Yamauchi LM, Yamada-Ogatta SF. The Antibacterial and Wound Healing Properties of Natural Products: A Review on Plant Species with Therapeutic Potential against *Staphylococcus aureus* Wound Infections. Plants. 2023; 12: 2147. https://doi.org/10.3390/ plants12112.

[92] Kolkar KP, Malabadi RB, Chalannavar RK, Divakar MS, Moramazi S. Probiotic hemp milk-market growth: An updated review. World Journal of Biology, Pharmacy and Health Sciences. 2025; 23(02): 133-143.

[93] Chalannavar RK, Divakar MS, Kumar A, Malabadi RB*, Swathi, Kamble AA, Karamchand KS, Kolkar KP, Moramazi S, Munhoz ANR, Castaño Coronado KV. Wound Healing: Traditional plant based and Modern wound dressing-An update. International Journal of Biological and Pharmaceutical Sciences Archive. 2025; 09(02): 044-066.

[94] Kolkar KP, Malabadi RB, Chalannavar RK, Divakar MS, Swathi, Kamble AA, Karamchand KS, Castaño-Coronado KV, Munhoz ANR, Mammadova SS. Industrial *Cannabis sativa* (Fiber or Hemp): Hemp Cottonization-Advantages and Current Challenges. International Journal of Science and Research Archive. 2025;14(03): 1233-1267.

[95] Malabadi RB, Kolkar KP, Chalannavar RK, Baijnath H. Plant Based Leather Production-An update. World Journal of Advanced Engineering Technology and Sciences. 2025; 14(01): 031-059.