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A Review on Therapeutic Potential of Khus Grass and Alum in Wound Healing: Advances in Non-woven Mat Fabrication

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A B S T R A C T

The process of wound healing is complex and includes four stages hemostasis, inflammation, proliferation and remodeling. In recent time, the trend in research has been to develop composite materials by combining natural bioactive compounds with modern biomaterials to promote tissue regeneration and inhibit infection. Vetiveria zizanioides, also known as Khus grass in indigenous medicine, contains antioxidants and possess antimicrobial, anti-inflammatory and tissue regenerative effect thereby serving as a potential phytotherapeutic agent for treatment of wounds. Alum (Potassium Aluminum Sulfate) an age-old analogue which is known for its astringent, hemostatic and antiseptic property, which supports Khus grass in binding the clots & prevents the growth of microorganisms. The intersection of these natural agents with the technology of non-woven mat fabrication including electrospinning and solvent casting provides a unique opportunity for bioactive wound dressing design. Non-woven wound dressing has high porosity and fluid up-taking, oxygen permeability and a sustained release platform for therapeutic agents. This review highlights the recent advances in the incorporation of Khus grass extracts and alum into non-woven scaffolds, evaluating their synergistic roles in enhancing wound healing outcomes. The combination of traditional therapeutic compounds with modern fabrication techniques may pave the way for sustainable, cost-effective and highly efficient wound care materials.

Keywords: Vetiveria zizanioides, Potassium Aluminum Sulfate, Wound management, non-woven wound dressing, bioactive scaffolds.

1. Introduction

The process of healing wounds occurs throughout four overlapping phases that are hemostasis (the process of stopping bleeding), inflammation (the body's natural reaction to irritants), proliferation (the creation of new tissue) and remodeling (the alteration of existing tissue). Each of these phases allows for the restoration of structural integrity and function to an area of tissue that has been damaged (Gurtner et al., 2008). Many clinicians face the challenge of managing wounds due to the increasing numbers of patients presenting to hospital emergency departments with chronic wounds, (Guo & DiPietro, 2010). Typical dressings used to protect wounds, such as cotton gauze, synthetic film, and/or plastic film, are designed mainly as protective barriers and are therefore typically unable to facilitate cell regeneration or prevent microbial colonization (Boateng et al., 2008). As a result of this issue, many manufacturers have developed bioactive wound dressings which are intended to enhance the healing process by delivering specific therapeutic agents to the wound site that promote cell proliferation, provide antitoxic protection against infection, and stimulate tissue remodeling.

Recent research into plant-based products or phyto-products, has revealed many new applications. Phytochemicals have been recognized for having many properties, including their low toxicity, their ability to be degraded by biological processes, and their abilities to neutralize harmful free radicals; but also, their limited to no adverse reactions when used in humans (Mukherjee et al., 2019). A popular plant for medicinal applications is Khus grass (Vetiveria zizanioides). Due to its wide variety of pharmacological effects, khus grass has become increasingly popular due to the different uses of khus grass extracts. The essential oils of khus grass contain many bioactive compounds, including the sesquiterpene β-vetivone; as well as many phenolic acid derivatives, such as vemiferoic acid; and phenolic compounds with antioxidant properties. These compounds have been shown to stimulate fibroblast proliferation, collagen synthesis, and the regeneration of epithelial cells in human skin, which suggests that khus grass may be developed as a phytotherapeutic agent for wound healing in the future (Chauhan et al.,2020).

For many centuries, alum (potassium aluminum sulfate) has been applied as a topical antiseptic, astringent and hemostatic agent in a manner similar to that of Khus grass. Aleph reduces bleeding, promotes coagulation, reduces edema and inhibits bacterial growth when used to treat open wounds. As a result, it increases the rate of healing through contraction of the wound and decreases the likelihood of development of infection (Basha et al. 2018). Therefore, the combined use of Kuss grass and alum is expected to have a synergistic benefit by providing an antioxidant and regenerative effect, as well as to enhance the stability and antimicrobial activity of the clot.

However, inherently direct usage of natural agents like khus grass and alum might be hindered by issues like low stability, unregulated release, and short retention at the wound site (Pitt et al., 2022). To resolve these problems, the latest progress in biomaterial production, particularly non-woven mat

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technologies, have opened up novel possibilities of embedding natural substances in controlled-release topical dressings (Yadav et al., 2023). Non-woven wound dressing produced by electrospinning or solvent casting methods are structurally ECM-like as they have very high porosity, good oxygen permeability and they are able to retain moisture which is very important in a wound healing process (Sill & von Recum, 2008). In addition, the mentioned systems provide a prolonged release of bioactive agents, thus the interval between dressing changes can be extended and the possibility of infection is lowered (Zhou et al., 2019).

The fusion of age-old bioactives such as khus grass and alum with high-tech non-woven mat production techniques is a significant move in the direction of creating environmentally friendly, inexpensive, and very efficient materials for wound treatment. This paper is committed to uncovering the medicinal potential of these natural substances and assessing their loading into bioactive nonwoven scaffolds, thereby putting forward the beneficial interactions coexisting in the system that enhance wound healing. After all, melding of traditional medicinal lore with cutting-edge biomaterial research might well be the harbinger of a new era in sustainable wound management systems.

2. Phytochemistry and Therapeutic Properties of Khus Grass

Vetiveria zizanioides, commonly known as khus grass or vetiver, is a perennial grass species which produces aromatic root scents while offering multiple health benefits through its medicinal applications. Vetiver root essential oils contain several pharmacological compounds which result from the active components that consist of volatile and non-volatile substances including sesquiterpenes, and sesquiterpenoids such as khusimol, and alpha-vetivone, and beta-vetivone, and eudesmol according to Kumar et al. 2021 and Barcellos-Silva et al. 2025. The non-volatile extract from vetiver contains three types of components (phenolics, flavonoids, and tannins) that provide antioxidant and anti-inflammatory effects. The non-volatile extracts contain alkaloids and saponins as their other active components. The chemical composition between these two substances should remain stable across different soil types and extraction methods. Sesquiterpene alcohols stay as the main active component at the highest concentration level.

The root essential oil of vetiver, called vetiver oil (VEO), is very complex and contains more than 150 different volatile compounds among which are khusimol, vetiverol, eudesmol, vetivone, and vetivenic acid that exhibit antioxidant, antimicrobial, and anti-inflammatory activities to a significant extent (Gunasekar, 2025; Durge et al., 2021). The oxygenated sesquiterpenes bind to biological membranes and enzymes, thus tissue regeneration and wound healing are improved (Yadav et al., 2023). Polar extracts from roots and leaves are loaded with phenolics, flavonoids, tannins, terpenoids, alkaloids, and saponins, which are capable of performing free radical scavenging and metal-chelating activities, protecting tissues from oxidative insult, and inhibiting inflammatory mediators (Kandsi et al., 2024; Chauhan et al., 2020).

Khus grass promotes wound healing through multiple mechanisms. The antioxidant properties of this substance neutralize reactive oxygen species (ROS) to speed up fibroblast growth and tissue regeneration (Gurtner et al., 2008). The body achieves anti-inflammatory effects through two main processes which involve decreasing pro-inflammatory cytokines and blocking cyclooxygenase and nitric oxide synthase enzymes to treat both swelling and discomfort (Barcellos-Silva et al., 2025; Guo & DiPietro, 2010). Antimicrobial properties of khusimol and β-vetivone stop the growth of Staphylococcus aureus and Escherichia coli and Pseudomonas aeruginosa which leads to infection and biofilm prevention (Basha et al., 2018). The application of topical treatments promotes faster wound healing through its impact on fibroblast movement and collagen production and epithelialization and blood vessel formation (Gunasekar, 2025; Yadav et al., 2023). Studies show vetiver extracts prove safe when used in small amounts which scientists use to develop stable non-woven wound dressings and hydrogels that deliver controlled release and reduce skin irritation (Durge et al., 2021; Sill & von Recum, 2008).

3. Pharmacological Actions of Alum in Wound Healing

Alum is a compound that has the ability to create an immediate stop to bleeding (Hemostasis), and therefore is considered a topically applied material for treating wounds because of its anti-inflammatory as well as antibacterial properties. The way it achieves this is by coagulating (clotting) the protein in tissue, which causes a constriction of blood vessels due to swelling of the blood vessel walls, and therefore reduces the permeability of capillaries. This creates a temporary scaffold, or framework, for the regeneration of new tissue (Granulation tissue). As an anti-microbial agent, it works by disrupting the pH balance of bacteria as well as preventing bacterial (and yeast and some viruses) growth (inhibition). Due to this property, it has become common use for preventing secondary infections and biofilm formation associated with a wound. Alums also modulate the inflammatory response to injury, creating an environment where fibroblast cells and epithelial keratinocytes can proliferate (because it promotes healing of soft tissue) (Shah et al., 2009).

In support of tissue regeneration, alum stabilizes collagen during the initiation (contraction), and repair of granulation tissue (Epithelialization, and granulation tissue maturation), and helps to minimize scarring due to its astringent action. As a topical antiseptic and/or anti-inflammatory, alum is considered a safe, effective treatment; however, overuse may lead to tissue irritation or toxicity. To improve efficacy, it has been incorporated into various controlled-release formulations of non-woven wound dressing and/or hydrogels. Combining alum with natural phytochemical compounds (such as Trigona spp. Owl) has shown enhanced synergistic effects (Yadav & Srivastava, 2018).

Table 1. Major Phytochemical Constituents of Vetiveria zizanioides and Their Biological Roles

Parameter	**Khus Grass Extract**	**Alum**
Antioxidant Activity	Strong	Weak
Antimicrobial Action	Broad-spectrum (especially Gram-positive bacteria)	Strong bactericidal effect via protein precipitation
Anti-inflammatory Effect	High	Moderate
Hemostatic Activity	Mild	Strong, rapid clot formation
Tissue Regeneration	Stimulates fibroblasts, collagen deposition	Supports contraction & epithelialization
Stability	Sensitive to heat & oxidation	Very Stable
Limitations	Volatile compounds degrade rapidly	High concentration can be cytotoxic

4. Nonwoven Mat Fabrication Techniques for Wound Dressings

Non-woven mat products are polymer-based matrix scaffolds that do not incorporate traditional weaving or knitting processes to produce a lightweight and flexible porous material, which makes them suitable for wound healing purposes. The structure of each non-woven mat is similar to an extracellular matrix (ECM) since they maintain properties that allow for cell adhesion, proliferation, and regeneration of tissue (Sill & von Recum 2008). Due to their higher surface area, interconnected porosity, and ability to incorporate bioactive agents efficiently, non-woven wound dressing provide a superior alternative to conventional dressings for treatment of chronic and acute wounds (Boateng et al. 2008; Zhou et al. 2019). Non-woven wound dressing also help retain moisture, facilitate delivery of oxygen to the wound, and absorb exudates necessary for maximum healing.

The most commonly used technique for creating non-woven dressings is electrospinning. Electrospinning creates nanofibers that mimic the composition of fibrils found in the ECM and has the capability of providing precision control over fiber diameter, high levels of porosity, and the ability to encapsulate bioactive compounds through blending, co-axial spinning, and immobilization on the surface of the mat (Yadav et al. 2023). Alternative production methods include solvent casting, melt-blown spinning, phase separation, centrifugal spinning, and freeze-drying; however, these methods offer advantages over electrospinning such as improved uniformity of drug distribution, scalability, and 3-dimensional (3D) porosity. Non-woven dressings can be utilized to deliver bioactive agents by providing controlled release of the active ingredients, mechanical protection, ECM mimicry, and enhanced cellular migration (Sill & von Recum 2008; Boateng et al. 2008). Understanding the required properties of a polymer to achieve sufficient therapeutic benefits depends on optimal selection of polymer type, diameter of fiber, % porosity, drug loading, and biocompatibility.

Table 2. Comparative Properties of Khus Grass Extract and Alum in Wound Healing

Parameter	**Khus Grass Extract**	**Alum**
Antioxidant Activity	Strong	Weak
Antimicrobial Action	Broad-spectrum (especially Gram-positive bacteria)	Strong bactericidal effect via protein precipitation
Anti-inflammatory Effect	High	Moderate
Hemostatic Activity	Mild	Strong, rapid clot formation
Tissue Regeneration	Stimulates fibroblasts, collagen deposition	Supports contraction & epithelialization
Stability	Sensitive to heat & oxidation	Very Stable
Limitations	Volatile compounds degrade rapidly	High concentration can be cytotoxic

5. Incorporation of Khus and Alum into Nonwoven Wound dressing

Non-woven wound dressing loaded with khus extract and alum offer synergistic wound-healing effects as a result of their antioxidant, anti-inflammatory, antimicrobial, and hemostatic properties being combined with the structural advantages of the wound dressing (Yadav et al., 2023). Incorporating bio actives in polymer solutions ensures that the components are evenly distributed and that there is a sustained release, whereas surface immobilization allows for rapid activity in the beginning and helps to keep the sensitive compounds intact. With the help of coaxial electrospinning, core–shell fibers can be obtained which makes it possible to have controlled release as well as protection of the thermally sensitive extract (Sill & von Recum, 2008).

As a result of the combination, the four processes of hemostasis, antimicrobial protection, inflammation modulation, and tissue regeneration are improved. Alum, which promotes clotting, is complemented by the khus compounds that not only inhibit bacterial growth but also neutralize ROS, thus, a healing environment that is controlled is created. Fibroblast proliferation, collagen deposition, epithelialization, and wound closure are the processes that are enhanced by the wound dressing loaded with both the agents (Gunasekar, 2025; Chauhan et al., 2020). The investigation on chitosan-PEG wound dressing with alum and PCL wound dressing with khus extract that are electrospun is indicative of clotting, antimicrobial activity, and tissue repair that are accelerated. Incorporation that is effective is dependent on factors such as chemical compatibility, concentration optimization, release that is controlled, and retention of bioactivity after sterilization (Zhou et al., 2019; Yadav et al., 2023).

Table 3. Representative Studies Incorporating Natural Bioactive Agents into Nonwoven Wound dressing

Polymer Matrix	**Bioactive agents**	**Fabrication Techniques**	**Key Outcomes**	**Reference**
Chitosan–PEG	Alum	Solvent casting	Enhanced hemostasis, antimicrobial action	Basha et al., 2018
PCL nanofibers	Khus extract	Electrospinning	Improved fibroblast adhesion & wound closure	Yadav et al., 2023
PVA/Chitosan	Herbal extract	Electrospinning	Sustained release, reduced infection	Zhou et al., 2019
PLA nanofibers	Essential oils	Coaxial electrospinning	Controlled release, improved biocompatibility	Sill & von Recum, 2008

6. Mechanisms of Wound Healing with Bioactive Non-woven wound dressings

Bioactive non-woven wound dressings enhance the process of wound healing via synergistic mechanisms. Alum provides hemostasis by interacting with proteins and platelets of blood, promoting clot formation, while the fibrous mat stabilizes the clot and supports inflammatory cell migration (Basha et al., 2018; Boateng et al., 2008). Khus grass extract and alum together provide antimicrobial protection, preventing infections that impede healing. The combination of khus grass' anti-inflammatory and antioxidant properties with how alum decreases inflammation is leading towards developing the ideal environment in which fibroblasts can proliferate, deposit collagen, undergo Epithelialization, and produce new blood vessels (Yadav et al., 2023; Gunasekar,2025).Together with the properties mentioned above, the structure of the mat allows for controlled release of bioactive compounds, management of fluids, and mimicking of the ECM, all of which promote faster healing and lower the risk of scarring.

7. Critical Analysis of Existing Studies

Existing literature suggests that khus grass extract, alum and non-woven materials have potential therapeutic roles in the treatment of chronic wounds. However, almost all of the studies investigating these individual components as treatments highlight limitations and inconsistencies. One constraint identified in many investigations is the lack of standardized methodologies, such as extraction technique varieties and resultant phytochemical compositions, which can affect results. The majority of studies that evaluate the use of alum-based formulations show strong antimicrobial activity and hemostasis; however, limited data are available to support their use in sustained-release systems. Non-woven wound dressing containing natural active compounds have shown the ability to support cell growth and healing in vitro; however, most studies involve small-scale laboratory evaluations, and too few studies have occurred in vivo. There have been only a handful of studies regarding the potential for synergistic activity between khus and alum when used together within one scaffold, and as such, this area is under-researched. Many studies also fail to fully detail all issues surrounding polymer-drug compatibility, release kinetics, or mechanical integrity of these materials when they are placed in a physiological environment.

Though it appears that there are positive attributes associated with the use of each of the three components, there are not enough comparisons between combined applications to make strong clinical assertions. More methodologically rigorous research is needed to confirm the efficacy of these components when combined and used to treat chronic wounds with the respect that is deserved through experimental evidence.

8. Challenges and Limitations of the wound dressings

Although khus grass and alum-based non-woven wound dressings have great therapeutic potential, there are numerous challenges these products face. Khus grass phytochemicals can undergo degradation of antioxidant and antimicrobial effectiveness during processing or storage (chauhan et al., 2020). In addition, the potential for cytotoxicity from the higher amounts of alum and the complexity of optimizing the release kinetics from the wound dressings are significant challenges (basha et al., 2018). Mechanical properties, reproducibility and scalability are also key issues, as the regulatory approval process requires a substantial amount of testing for biocompatibility and clinical safety prior to the release of any wound dressing (yadav et al., 2023).

In addition, the effects of processing on sensitive phytochemicals such as sesquiterpenes found in khus grass due to electrospinning processing variables such as voltage, solvent system, humidity and polymer concentration can negatively influence the chemical properties of these phytochemicals. Scalable manufacturing of composite wound dressings remains an area of challenge due to inconsistencies in chemical profiles across batches and high cost of completing sterilization processes. Furthermore, the environmental conditions of solubilized aluminium and the localized acidity associated with alum can affect the mechanical integrity of natural polymer wound dressing after long-term use. The biochemical and stability standards for herbal-loaded wound dressings are quite stringent before clinical approval.

9. Future Perspectives and Clinical Applications

Khus Grass and Alum would have multiple applications related to its bioactive properties when used as a non-woven to treat wounds. There are three clinical applications for this dressing product, beginning with burn wounds that are subjected to oxidative stress/infection where the anti-oxidizing and antimicrobial activity of Khus Grass and Alum can quicken epithelialization. The sustained release of bioactive substances (Khus Grass and Alum) from the dressing material helps with diabetic ulcers. These same properties may assist with post-surgical incisional bleeding due to the hemostatic properties of alum and increased collagen deposition due to khus, may help in traumatic injuries and pressure ulcers by helping to resolve the imbalance between microbe loads and moisture levels that influence healing.

Research should focus on improved fabrication methods such as electrospinning and coaxial fiber formation for fibre formation control and bioactive release (Yadav et al. 2023). A further enhancement of mechanical stability and localized delivery will be the combination of biodegradable polymers and nanocomposites (Zhou et. al. 2019). The combination of Khus Grass and Alum provides excellent hemostatic, antimicrobial, and tissue regenerative properties and would be useful in treating chronic wounds, burns, and post-operative wounds in one product (Gunasekar 2025; Basha et. al. 2018). Because they are plant derived and sustainable bioactive compounds they would enable large-scale production of low-cost products.

10. Limitations of the Review

This review is limited by variability in obtainable data, as many studies differ in extraction procedure, polymer compositions and evaluation models, making direct comparisons difficult. There are limited studies on khus grass and alum that explore their potential synergistic effects when combined. Most available research is preclinical with little evidence of large clinical trials for herbal-based non-woven dressings.

11. Conclusion

Khus grass and alum are two natural compounds, which when administered together, show great promise in their combined therapeutic effect in promoting accelerated healing of wounds. They have demonstrated their ability to provide antimicrobial protection, support rapid clotting, protect against oxidative damage, and stimulate tissue regrowth/repair. Additionally, by using these compounds as a component of non-woven wound dressing, the incorporation of these bioactive materials into the final product allows for greater stability and extended release of bioactive compounds, and since the non-woven mat products are similar to an extracellular matrix (ECM) in structure, they maintain moisture and provide structural support while promoting tissue growth/repair. Although the existing data supports the efficacy of khus grass and alum in promoting healing of wounds, additional studies are needed to improve the manufacturing process, assess the compatibility of these compounds with other materials, and evaluate their long-term safety and efficacy when used in a clinical environment. The continued study of these materials and the standardized development and large-scale manufacturing of khus grass and alum-based composite wound dressings will lead to the creation of environmentally sustainable, affordable, and highly effective products for clinical use.

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