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Review

Natural Polymers from Plants are Used in Wound- Healing Dressings and Gels

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Abstract

Natural polymers derived from plants have gained significant attention in the field of wound healing due to their biocompatibility, biodegradability, and ability to promote tissue regeneration. These polymers, such as alginate, chitosan, and cellulose, possess unique properties that facilitate moisture retention, provide a protective barrier against infections, and enhance the healing process. The incorporation of natural plant extracts into these polymeric matrices further enhances their therapeutic potential by introducing bioactive compounds that can reduce inflammation and accelerate healing. This review explores the various types of natural plant-based polymers used in the formulation of wound-healing dressings and gels, highlighting their mechanisms of action, advantages over synthetic alternatives, and potential applications in modern medicine. The findings suggest that the integration of natural polymers in wound care not only improves healing outcomes but also aligns with the growing demand for sustainable and eco-friendly medical products.

Keywords: Natural Polymers, Wound Healing, Plant-derived, Biopolymers

INTRODUCTION

1.WOUND HEALING

A complex series of cellular and molecular processes work together to restore the structural and functional integrity of wounded tissues while also restoring their strength. This process is known as wound healing. It involves ongoing interactions between cells and between cells and the matrix, which enable the process to progress in various overlapping phases and processes, such as inflammation, wound contraction, re-epithelialization, tissue remodeling, and the angiogenesis-induced creation of granulation tissue.[1] Therefore, a deeper comprehension of the molecular mechanisms behind tissue regeneration and wound healing is essential.(Figure 1).[2] Additionally, the material that heals wounds promotes the healing and restoration of damaged tissue. The beneficial qualities of natural polymers, including collagen, gelatin, chitin, chitosan, heparin, alginates, and silk fibroin, make them popular for use in wound healing applications. In addition to promoting re-epithelialization, a good wound healing substance should offer a favorable environment for cell migration, proliferation, and differentiation. When it comes to wound healing, the ultimate goal is for the wounded area to fully return to its natural state without any discomfort or visible scars.[7]

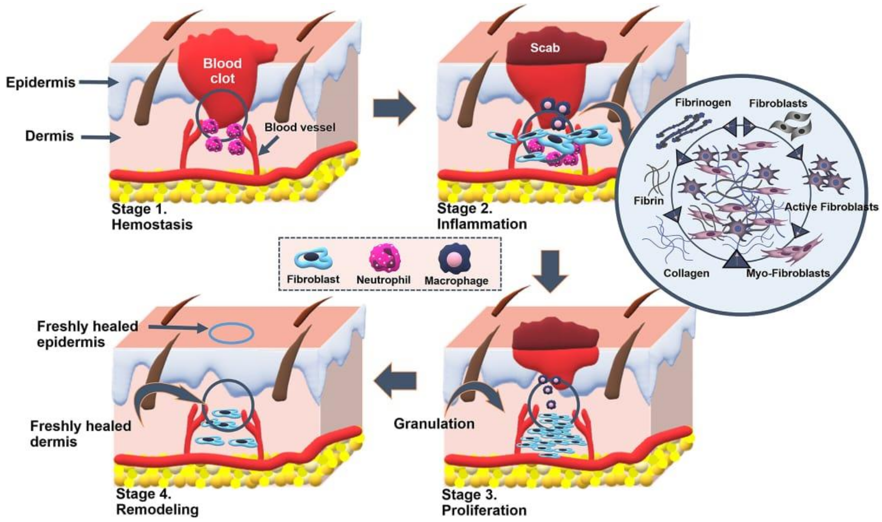

Fig 1: Stages of wound healing [2]

STAGE- 1 Hemostasis: cross-linked fibrin along with aggregated platelets help to stop bleeding (seconds to hours)
STAGE-2 Inflammation activation and recruitment of immune cells drive secretion of pro-inflammatory cytokines, promote recruitment of fibroblasts, epithelial cells and endothelial cells, monitor infection and response (hours to days)
STAGE-3 Proliferation of fibroblasts and collagen deposition, formation of new blood vessels, granulation tissue, new epithelium (days to weeks)
STAGE-4 Tissue remodelling maturation and modification of extracellular matrix. Increase in tensile strength of the wound (weeks to months) [6]

2. NATURAL POLYMERS

A polymer is a macromolecule, or huge molecule, made up of structural units that repeat. Covalent chemical bonds are usually used to join these subunits. In general, polymers can be divided into three categories: natural, synthetic, and semi-synthetic. Materials with high molecular weights that come from natural sources, like plants, microbes, and animals, are known as natural polymers. Natural polymers continue to be appealing when compared to synthetic and semi-synthetic ones, mainly because they are affordable, easily accessible, and capable of a wide range of chemical alterations. Because of their origin, they may also be biodegradable and compatible. Natural polymers have a wide range of applications in the food, cosmetic, and pharmaceutical industries. Natural polymers are biogenic, and their biological characteristics—such as their capacity to recognize and interact with cells, their enzymatic degradability, their resemblance to the extracellular matrix, and their chemical flexibility—make them ideal drug delivery materials.[3] Plant-derived polymers are specifically used in pharmaceutical formulations for the production of viscous liquid formulations, implants, films, beads, microparticles, nanoparticles, inhalable and injectable systems, and solid monolithic matrix systems. 4-6 As binders, matrix formers or drug release modifiers, film coating formers, thickeners or viscosity enhancers, stabilizers, disintegrants, solubilizers, emulsifiers, suspending agents, gelling agents, and bioadhesives, polymeric materials have served a variety of purposes in various dosage forms.[4]

2.1. Ideal properties of polymers

1.It must be inert and environmentally friendly.
2. It must not be harmful.
3. The administration should be simple.
4. It should be simple and affordable to make.
5. It should be strong mechanically.
6. It must work well with bodily fluids.
7. It shouldn't work pharmacologically. [5]

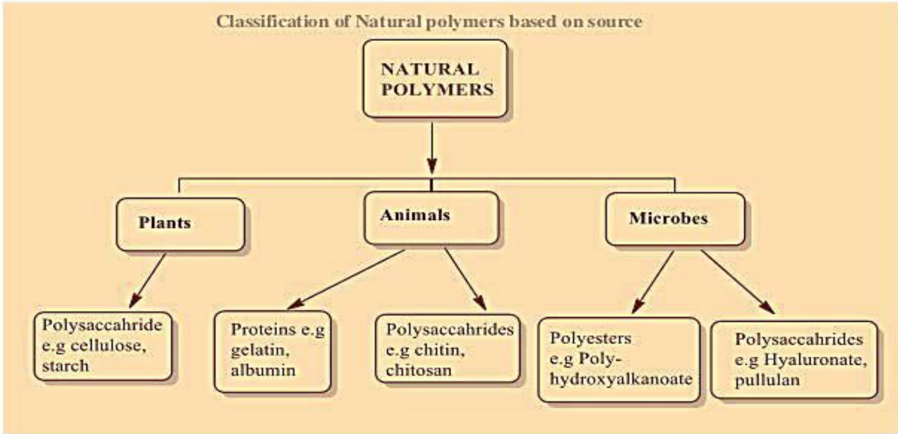

Fig 2: Classification Of Natural Polymers.[3]

3.Polysaccharides

Polysaccharides (natural polymers) can be readily obtained from a variety of sources, including microbial sources such as gelatin, starch, cellulose, and chitosan; animal sources include dextran, glucan, and alginate; and vegetal sources such as alginate, dextran, and glucan. Certain polysaccharides, which are given as hydrogels, help cure burns and wounds: Alginic acid, hyaluronic acid, glucans, dextrans, and cellulose are examples of neutral sulfated polysaccharides, while chitin and chitosan are examples of basic sulfated polysaccharides. For creating nanofibrous composites in the field of regenerative medicine (tissue engineering, wound dressing), electrospun, dextran, cellulose, and starch are very efficient materials.In addition to being non-cytotoxic, hydrogel has a high capacity for water absorption (swelling ratio up to 4,000%), which suggests quick hemostatic action and inhibits the formation of exudate and dryness in the wound bed. It is possible to treat open wounds and burns by adding antibiotics and antimycotic medications to the hydrogel to prevent bacterial biofilm encroachment.[8]

3.1POLYSACCHARIDES FROM PLANT ORIGIN
3.1.1 CELLULOSE

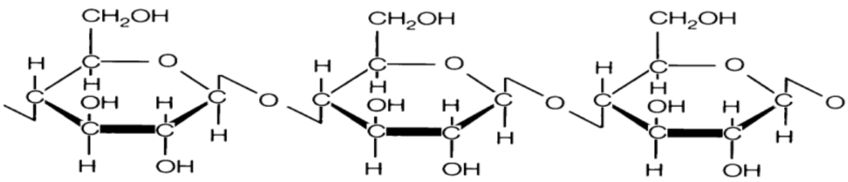

Fig 3: Image of Cellulose.[3]

Fig 4: Sources of Cellulose.[9]

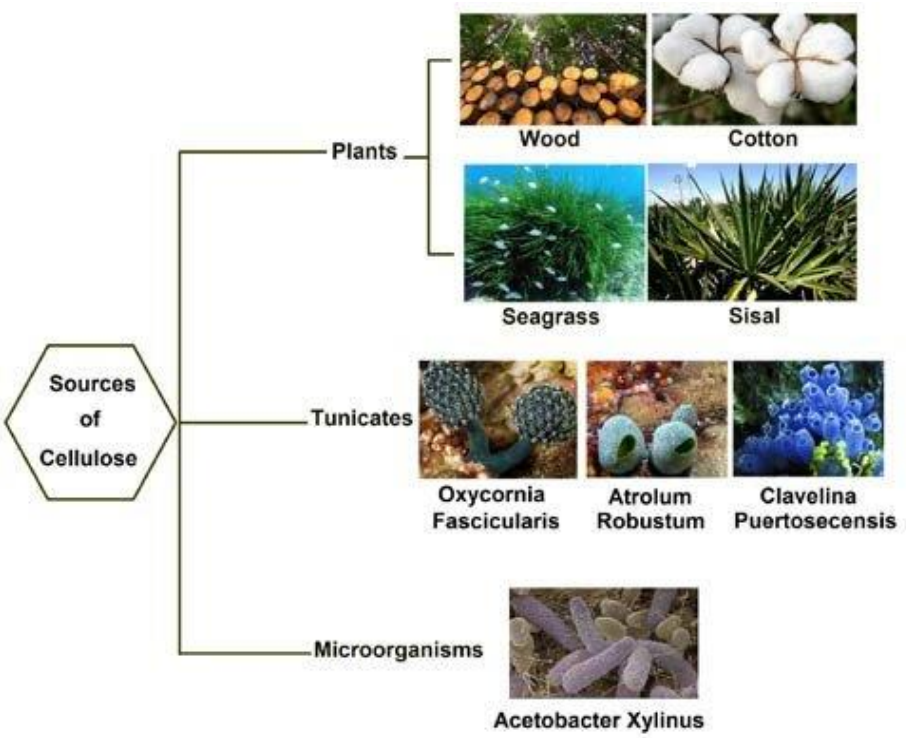

Fig 4.1: Sources Of Cellulose.[10]

Composition:It is an organic polymer with the formula ($C6H10O5$)n that is made up of a linear chain of several hundred to more than ten thousand β (1→4) connected D-glucose units. Pectin, cellulose, and hemicelluloses make up the majority of the plant cell wall.[3]

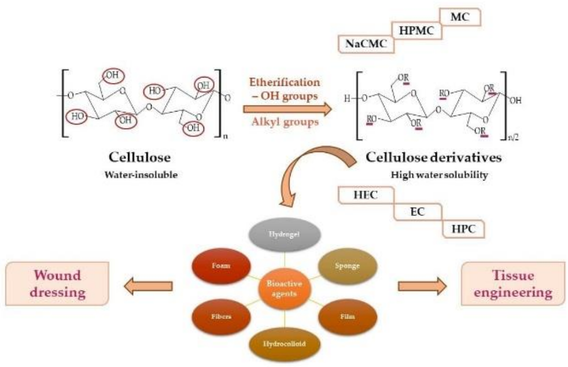

Fig 5: graphical abstract[21]

Applications

The pharmaceutical industry primarily uses microcrystalline cellulose as a diluent/binder in tablets for both the direct compression and granulation operations. Drug formulations use carboxylated methyl cellulose as an ointment basis, film-coating agent, and binder, among other uses. The fibers of cellulose acetate are utilized in wound dressings.[3]

3.1.2 AGAR

Biological source: The dried gelatinous material known as agar is derived from various sources, including Gelidium amansil Lamouroux and Glidium cartilagineum Gall.[12]

Chemical composition: Heterogeneous polysaccharides consisting of two components

(a) Agarose (70%),

(b) Agaropectin (99%)[12]

APPLICATION

Agar is a highly biocompatible and non-immunogenic polymer that can be used to carry cell growth factors to damaged tissues and organs and create a gel that resembles the physical properties of the extracellular matrix. shown that a binary mixture of agar and keratin is suitable for use in wound healing and skin regeneration since it is non-toxic and promotes cell proliferation. A novel squalene-loaded agar-based emulgel scaffold has been shown to considerably compress the wound area with high re-vascularization and macrophage polarization, hence speeding up the healing of burn wounds. Created a nanobiocomposite scaffold for wound healing applications using zinc chromite nanoparticles, extracted silk fibroin solution, and cross-linked lignin-agarose hydrogel. To address wound healing, fumaric acid was synthesized and added to an agar-silver hydrogel. This hydrogel demonstrated increased collagen deposition and angiogenesis, a faster pace of wound healing, and a synergistic antibacterial activity against microorganisms.[11]

3.1.3 STARCH

In plants, starch is the most prevalent storage polysaccharide and a significant source of carbohydrates. Its biocompatibility and degradability have led to extensive research in the biomedical and pharmaceutical sectors. The substance is also thought to be non-immunogenic and non-toxic. Its biocompatible qualities allow starch to be made from a variety of sources, including rice, corn, and potatoes. Two polymers, amylose and amylopectin, combine to form starch.[22]

Biological source: The polysaccharide granules that make up starch are derived from the tubers of the potato Solanum tuberosum L., the grains of maize Zea mays L., rice Oryza sativa L., and wheat Triticum aestivum L.[12]

Chemical composition: Starch contain generally a mixture of two polysaccharides, amylopectin (more than 80%) and Amylose (20%).[12]

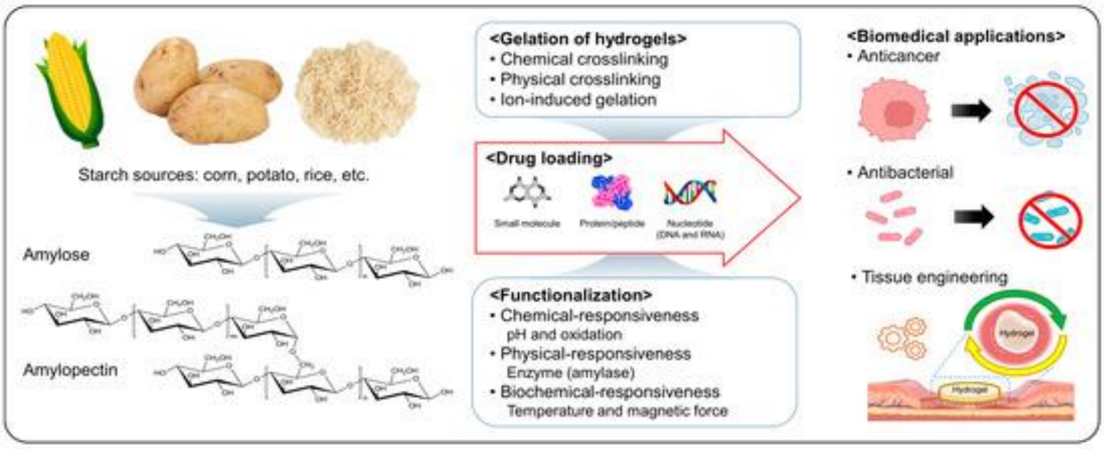

Fig 6: Starch based hydrogels

Applications

Additionally, starch may be readily altered chemically, which makes it suitable for tissue engineering and medication administration. In order to create drug-loaded hydrogel systems that offer regulated release over an extended period of time, starch-based hydrogels can be used as efficient transporters for medicinal substances such proteins and medications. Starch's non-ionic nature makes it simple to combine with other polymers. Increased porosity (82.51%) of a gelatine-starch scaffold can make it ideal for cell development, vascularization, and cellular contact. It can also improve the mechanical properties of the final polymer blend by increasing its pore size and water uptake. Scaffolds based on starch can serve as a substrate for cell adhesion and have a good rate of biodegradation. the creation of starch-gelatine scaffolds for use in wound healing. According to this study, the scaffold can hasten wound closure and encourage tissue remodeling and rearrangement.[11]

3.1.4 GUAR GUM

Source: The refined endosperm of Cyamopsis tetragonolobus L. Taub. seeds is used to make guar gum [12].

Composition: Guar gum is a polysaccharide made up of the sugars mannose and galactose. Galactose residues are 1,6-linked to every second mannose to generate brief side-branches from the linear chain of β1, 4-linked mannose residues that makes up the backbone. [12]

Applications

The formulation of transdermal therapeutic systems uses carboxymethyl guar film. Bioactive compounds, including medications and natural ingredients, can be incorporated into guar gum-based films used for wound healing.[13] Recently, it has been investigated to manage a number of factors, such as swelling, degradation, mechanical behavior, and improved wound healing properties, by including honey into the structure of these biomaterials. [13]

Fig 7: Guar gum-based vehicles with potential use as wound dressings.[13]

4. POLYSACCHARIDES FROM ANIMAL ORIGIN

4.1Chitosan/chitin

Source:

The most prevalent organic component in the skeleton of invertebrates is chitin, a polysaccharide derivative with acetyl and amino groups. It is mostly found in arthropods, mollusks, and annelids. It is also a component of many fungi's spores and mycelia. Chitin undergoes alkaline deacetylation to yield chitosan. [12]

Chemical composition: Hydrogen bonds between and within molecules give chitosan its stiff crystalline structure. N-acetyl-D-glucosamine and D glucosamine copolymerize to form the chitosan molecule. [12]

Applications:

Inflammatory cells' ability to act during wound healing can be enhanced by chitosan. [11] Chitosan/chitin is a promising option for tissue engineering applications because of its resemblance to the structure of the extracellular matrix, which enhances cell adhesion and proliferation. [11] A chitosan/collagen scaffold fused with Thymosin beta-4 (TB4) showed a sustained release of TB4, which accelerated the migration and proliferation of glucose-treated human umbilical vein endothelial cells with increased angiogenesis, according to a study conducted on diabetic rats. [11]

4.2 ALGINATE

Source: Alginic acid salts include sodium alginate. It is the refined carbohydrate that is extracted from Laminaria species, a type of brown algae. [12]

Chemical composition: As a block of solely D-mannuronic acid and L-gluoronic acids in homopolymer or alternating the two in heteropolymeric blocks, these polymers are made up of two distinct monomers in variable proportions: D-mannuronic acid and L-gluoronic acids linked by a 1, 4-glucosidic linkage. [12]

Applications:

Additionally, this polymer possesses antibacterial qualities, low toxicity, conformability, high water absorption, and an ideal water vapor transmission rate all of which are critical attributes needed for wound dressings. [11]

According to the findings, wound healing improved by more than 90% in just 14 days. [11] Additionally, scaffolds for tissue engineering can be made with alginate. [11]

Alginate microspheres, alginate-chitosan, chito-oligosaccharides (COS) with collagen (alginate–chitosan–COS–collagen), and a combination of alginate, chitosan, and COS (alginate–chitosan–COS) have all been used as skin substitutes, showing better biocompatibility and mimicking the skin microenvironment. [11] Alginate and collagen were conjugated to create a drug delivery scaffold, and curcumin nanoparticles were added to improve the wound-healing process. [11]

5. PROTEINS FROM ANIMAL SOURCES

5.1COLLAGEN

The most prevalent protein in the human body is collagen, which also makes up the majority of the extracellular matrix. It plays a crucial part in wound healing and is the primary structural protein in the dermis. Collagen has thus been used in the creation of a number of skin scaffolds. [11]

Source: The main protein found in animal connective tissues is collagen. Collagen is most prevalent in pig skin, bovine hide, and the bones of cattle and pigs. [3]
Composition: Collagen is made up of various polypeptides, mostly glycine, proline, hydroxyproline, and lysine, and comes in 27 different varieties. Only the amount of glycine in the collagen chain affects its flexibility. [3]
Application

A significant part of the human skin's dermis, collagen has a special triple helix structure that gives the skin its mechanical strength and structural integrity. In contrast to other polymers, collagen serves a variety of biological purposes, including promoting the deposition of newly generated collagen and acting as a biological scaffold for cell adhesion, migration, and proliferation. Collagen is a common natural polymer used to make wound dressings because of its excellent biocompatibility, low antigenicity, and quick hemostasis. Acute and chronic ulcers have been shown to benefit from collagen dressings' ability to absorb significant volumes of wound exudate and support the preservation of the wound's physiological microenvironment. [14]

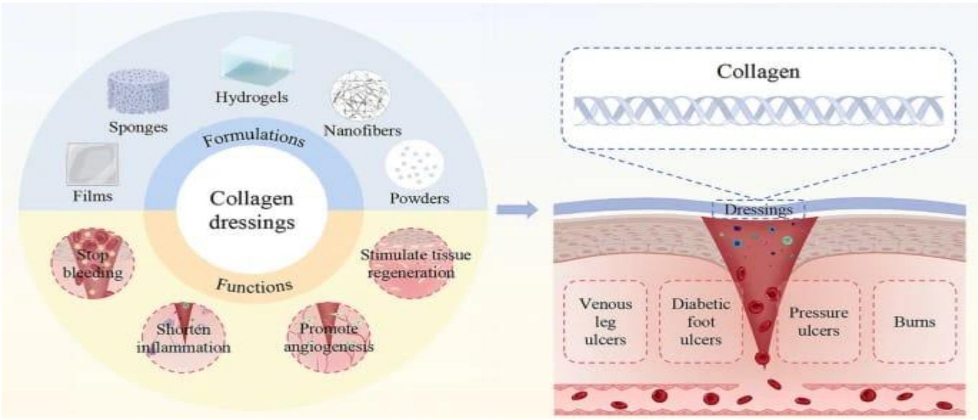

Fig 8: Collagen dressings[14]

Collagen wound dressings can be classified as films, sponges, hydrogels, nanofibers, and powders based on the various scaffold material formulations. (FIG:9) Depending on the kind, stage of healing, and state of the wound, selecting the right kind of collagen wound dressing is essential.[14]

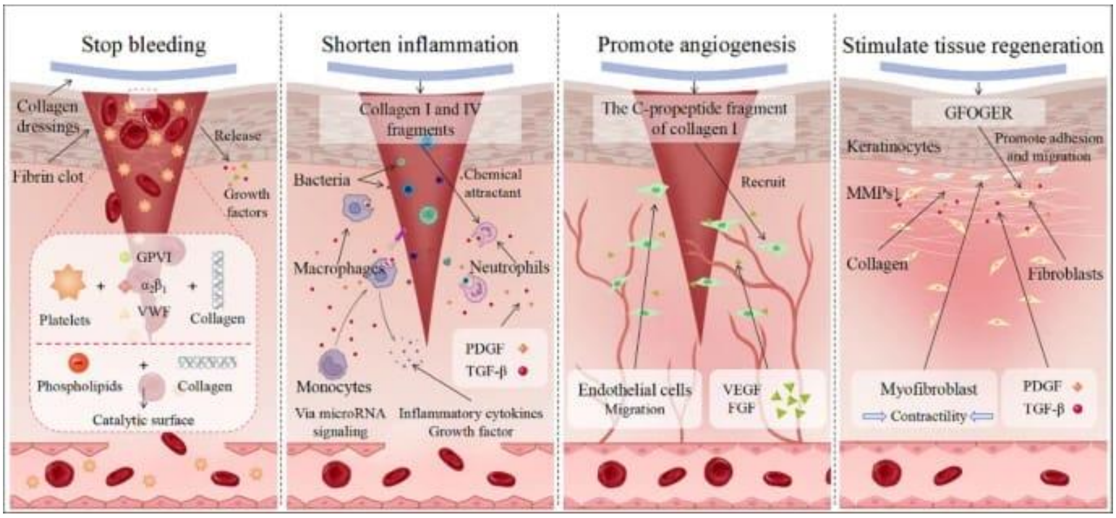

Fig 9: The roles of collagen dressings in wound healing.[14]

5.2 GELATIN

The natural polymer gelatin is produced by hydrolyzing nonsoluble Col. Because gelatin is a derivative of Col, it shares many of the same properties as Col. Gelatin has been shown to be flexible, stable, biocompatible with human tissues, and adaptable enough to serve as a scaffold base. [15]

Biological source: Collagen is partially hydrolyzed to produce gelatin, which is generated from the skin, white connective tissue, tendons, ligaments, and bone of sheep (ovis aries linn), ox (B0s tourur linn), and other animals. [12]
Chemical composition: Glycine, alanine, leucine, aspartic acid, argentine, lysine valine, cystine, and other amino acids are produced when the protein glutin, which makes up the majority of gelatin, is hydrolyzed. [12]
Application:
Proline, glycine, and hydroxyproline make up gelatin, which mimics the extracellular matrix in terms of amino acid makeup and is comparable to Col. [15]
The adhesion of cells is caused by the glycine amino acid content of the gelatin. [15] The results show that it has enhanced mechanical strength, hydrolytically and thermally stable qualities, and the ideal range of hydrophilicity and porosity, all of which speed up the healing process. [15] In particular, casting-produced gelatin-based antibacterial wound dressing has been shown to be an efficient dressing material. [15]

6.Hyaluronic Acid
Hyaluronic acid (HA) is a naturally occurring polymer that is one of the primary constituents of the extracellular matrix (ECM). Because of its distinct characteristics and various physiological roles, HA is crucial to the processes of wound healing and tissue repair. [16]

STRUCTURE OF HYALURONIC ACID

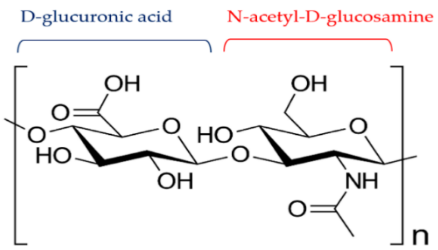

Fig 10: [17]

Glucuronic acid and N-acetylglucosamine repetitions are joined by a β-1,4 bond to form the naturally occurring linear polymer known as hyaluronic acid (HA) (Fig. 10). It is a linear polymer with a molecular mass between 104 and 107 Da with repeating disaccharide units of N-acetyl-D-glucosamine and D-glucuronic acid connected by β(1,4) and β(1,3) glycosidic links, respectively. [18]
Application:
The healing process's phases of proliferation, migration, and tissue maturation are all impacted by HA, which is known to activate keratinocytes. [19] Additionally, there is proof that collagen deposition is more organized and less degraded after hy-aluronic acid matrices are applied, and that extracellular matrix remodeling is improved. It increases the angiogenic response from the wound bed and keratinocyte migration and proliferation. [20] Leukocyte chemotaxis and the release of inflammatory cytokines such as IL-1β, TNF-α, and IGF-1 are stimulated by the aggressive breakdown of high molecular weight (HMW) HA into oligomers of low molecular weight (LMW) HA during the inflammation stage. [19]

CONCLUSION

The exploration of natural plant-based polymers for wound healing underscores a promising frontier in medical science, offering a sustainable, effective alternative to synthetic materials. The unique properties of these polymers, combined with the therapeutic benefits of plant extracts, present a holistic approach to wound care that not only accelerates the healing process but also promotes environmental sustainability. As research in this field continues to evolve, the potential for natural polymers to revolutionize wound management and align with eco-friendly practices in healthcare is increasingly evident, marking a significant step towards more natural, efficient healing methodologies.

REFERENCES

1. 1.Thakur R, Jain N, Pathak R, Sandhu SS. Practices in Wound Healing Studies of Plants. Evidence-Based Complementary and Alternative Medicine [Internet]. 2011;2011:1–17. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3118986/

2. 2.Tavakoli M, Sheyda Labbaf, Marjan Mirhaj, Salehi S, Alexander Marcus Seifalian, Mahboubeh Firuzeh. Natural polymers in wound healing: From academic studies to commercial products. 2023 Apr 12;
3. 3.Google Scholar [Internet]. Google.co.in. 2025 [cited 2025 Aug 25]. Available from: https://scholar.google.co.in/scholar?q=natural+polymers:+A+recent+review&hl=en&as_sdt=0&as_vis=1&oi=scholart#d=gs_qabs&t=1756149359211&u=%23p%3D_tf_ZHb_Q4AJ
4. 4.Google Scholar [Internet]. Google.co.in. 2025 [cited 2025 Aug 25]. Available from: https://scholar.google.co.in/scholar?q=natural+polymers+A+comprehensive+review&hl=en&as_sdt=0&as_vis=1&oi=scholart#d=gs_qabs&t=1756149597115&u=%23p%3De-A4mDp8tO0J
5. 5.Google Scholar [Internet]. Google.co.in. 2025 [cited 2025 Aug 25]. Available from: https://scholar.google.co.in/scholar?q=natural+polymers+as+potential+anti-aging+constituents&hl=en&as_sdt=0&as_vis=1&oi=scholart#d=gs_qabs&t=1756149754298&u=%23p%3DYV0EvIMxKygJ
6. 6.Google Scholar [Internet]. Google.co.in. 2025 [cited 2025 Aug 25]. Available from: https://scholar.google.co.in/scholar?q=effect+of+natural+polymer+material+on+skin+healing+based+on+internal+wound+microenvironment+a+review&hl=en&as_sdt=0&as_vis=1&oi=scholart#d=gs_qabs&t=1756150033325&u=%23p%3DztUh0XQp0soJ
7. 7.Natural Polymers. 2016.
8. 8.Google Scholar [Internet]. Google.co.in. 2025 [cited 2025 Aug 25]. Available from: https://scholar.google.co.in/scholar?q=application+of+natural+polymers+in+wound+dressings&hl=en&as_sdt=0&as_vis=1&oi=scholart#d=gs_qabs&t=1756150452949&u=%23p%3DX-H9vOhm6IwJ
9. 9.Mendes ISF, Prates A, Evtuguin DV. Production of rayon fibres from cellulosic pulps: State of the art and current developments. Carbohydrate Polymers. 2021 Dec;273:118466.
10. 10.Firoozeh Danafar. RECENT DEVELOPMENT AND CHALLENGES IN SYNTHESIS OF CELLULOSIC NANOSTRUCTURES AND THEIR APPLICATION IN DEVELOPING PAPER-BASED ENERGY DEVICES. Cellulose Chemistry and Technology. 2020 Mar 4;54(3-4):327–46.
11. 11.Oliveira C, Sousa D, Teixeira JA, Ferreira-Santos P, Botelho CM. Polymeric biomaterials for wound healing. Frontiers in Bioengineering and Biotechnology [Internet]. 2023 Jul 27;11:1136077. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10415681/
12. 12.Gupta A, Sharma N, Khinchi MP, Agrawal D. A REVIEW ON NATURAL POLYMER. Asian Journal of Pharmaceutical Research and Development [Internet]. 2017 [cited 2025 Aug 25];134–45. Available from: https://www.ajprd.com/index.php/journal/article/view/89
13. 13.Dodi G, Sabau RE, Crețu BEB ., Gardikiotis I. Exploring the Antioxidant Potential of Gellan and Guar Gums in Wound Healing. Pharmaceutics [Internet]. 2023 Aug 1;15(8):2152. Available from: https://www.mdpi.com/1999-4923/15/8/2152
14. 14.Shi S, Wang L, Song C, Yao L, Xiao J. Recent progresses of collagen dressings for chronic skin wound healing. Collagen and Leather. 2023 Oct 23;5(1).
15. 15.Naomi R, Bahari H, Ridzuan PM, Othman F. Natural-Based Biomaterial for Skin Wound Healing (Gelatin vs. Collagen): Expert Review. Polymers. 2021 Jul 14;13(14):2319.
16. 16.Antoszewska M, Sokolewicz EM, Barańska-Rybak W. Wide Use of Hyaluronic Acid in the Process of Wound Healing—A Rapid Review. Scientia Pharmaceutica [Internet]. 2024 Jun 1;92(2):23. Available from: https://www.mdpi.com/2218-0532/92/2/23
17. 17.Della Sala F, Longobardo G, Fabozzi A, di Gennaro M, Borzacchiello A. Hyaluronic Acid-Based Wound Dressing with Antimicrobial Properties for Wound Healing Application. Applied Sciences. 2022 Mar 17;12(6):3091.
18. 18.Google Scholar [Internet]. Google.co.in. 2025 [cited 2025 Aug 25]. Available from: https://scholar.google.co.in/scholar?q=Beneficial+Effects+of+Hyaluronic+Acid&hl=en&as_sdt=0&as_vis=1&oi=scholart#d=gs_qabs&t=1756152472646&u=%23p%3DY-U0RE0OQZYJ
19. 19.Kawano Y, Patrulea V, Sublet E, Borchard G, Iyoda T, Kageyama R, et al. Wound Healing Promotion by Hyaluronic Acid: Effect of Molecular Weight on Gene Expression and In Vivo Wound Closure. Pharmaceuticals. 2021 Mar 28;14(4):301.
20. 20.Google Scholar [Internet]. Google.co.in. 2025 [cited 2025 Aug 25]. Available from: https://scholar.google.co.in/scholar?q=the+role+of+hyaluronic+acid+in+wound+healing&hl=en&as_sdt=0&as_vis=1&oi=scholart#d=gs_qabs&t=1756153024464&u=%23p%3DMblx6_ZRhroJ
21. 21.Tudoroiu EE, Dinu-Pîrvu CE, Albu Kaya MG, Popa L, Anuța V, Prisada RM, et al. An Overview of Cellulose Derivatives-Based Dressings for Wound-Healing Management. Pharmaceuticals. 2021 Nov 24;14(12):1215.
22. 22.Lee CS, Hee Sook Hwang. Starch-Based Hydrogels as a Drug Delivery System in Biomedical Applications. Gels. 2023 Dec 4;9(12):951–1.