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Review on: Hydrogels as Drug Delivery System for Herbal Medicines

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Abstract

Hydrogels are more sophisticated smart polymers that have a variety of ligands and cross-links that enable highly controlled structures and various bio responsive functions Utilizing swellable multimeric polymers called hydrogels as a drug delivery system has drawn a lot of interest. These unique Properties that have garnered attention include sensitivity to temperature and pH, swelling in an aqueous medium, and sensitivity to various stimuli These are biomaterials. Because they are biocompatible, hydrogels have been shown to exhibit drug-protective properties, specifically for peptides along with proteins from the in vivo setting. These are swelling in polymers, also useful as attainable delivery systems Regarding tissue specific biologically active medications.

Furthermore, emphasis is placed on the use of adjuncts such as nanoparticles to enhance the therapeutic benefits of herbal medicines in hydrogel matrices. In general, hydrogels are a flexible medium that can be used to enhance the administration of herbal remedies, encouraging their clinical use and efficacy in contemporary medicine. Traditional medicine includes herbal medicine as a major component that is utilised to treat a variety of illnesses. For numerous years, Asians have used herbal remedies. Nevertheless, plant extract's medicinal value and applicability. Due to their affordability and efficacy in clinical treatment, naturally derived herbal medications with anti-inflammatory qualities are of interest.

We present a novel supramolecular hydrogel that consists of a self-assembling natural herb called Rhein, together with an oxidatively responsive cross-linked network that recognizes the actual host-audience relationships in between β-cyclodextrin along with ferrocene. The fact that the review represents the hydrogel as a drug delivery system in herbal medicine.

Keywords - Polymers, hydrogel, administration, anti-inflammatory, traditional, swellable

INTRODUCTION

Since the early 1960s, hydrogels, a unique kind of drug delivery, have been investigated. Initially, Lim together with Wicht Erle presented a type Hydrophobic gel known as interconnected hydroxyethyl methacrylate Hydrogels of (HEMA) which were created Regarding biological applications. [1,2] In physiological settings, hydrogels (hydrophilic polymers) swell and retain water as much as their dry weight. They are made of three-dimensional viscoelastic networks.[3]

Hydrogels Chemical cross-linking and physical contact can both support their morphological and physical integrity. Swellable networks with a large fluid absorption capacity are called hydrogels. Polymers, which might have natural or synthetic origins, constitute their main component. [4,5] Potential advantages include hydrophilicity, controlled release, biocompatibility, and intelligent drug delivery are just a few of the many benefits of hydrogels. Drug delivery systems hold great potential as therapeutic agents, serving as carriers to improve the efficacy of pharmaceuticals.

The advancement of drug delivery technologies has made polymeric hydrogel an appealing option. Hydrogels have a distinct advantage over other herbal medicine delivery technologies in whereby they are able to absorb big amounts from water. This ability has made it easier to include herbal remedies which are often watery in nature into hydrogels. Using herbal remedies has long been ingrained in Asian culture. Despite this, a number of issues, such as low absorption and a lack of targeting capacity, have limited the therapeutic efficacy of herbal medication. [6,7]

Water-friendly polymers are called hydrogels that have links between to create an arrangement of polymers. This allows between 10 and 20 percent of their body weight in water absorption.[8] Hydrogels can be utilised as biomaterials due to their unique properties, which include their water content, soft, elastic nature, and minimal adhesive force with water or biological fluids. Hydrogels' special physical characteristics allow for regulated disintegration, protect labile medications from degradation, and control the release of various actives, such as macromolecules, small molecules, and cells.[9]

Hydrogels are therefore uniquely suited for use in variety of regenerative medicine, medication delivery systems, hygienic goods, and wound dressings due to their unique capacity to address numerous formulation- and drug-related difficulties. You can use both natural and manmade polymers to make hydrogels; each type of polymer has advantages and disadvantages; thus, the application of the hydrogel and the intended drug delivery site should be taken into consideration when choosing a polymer.[10]

The classification of hydrogels

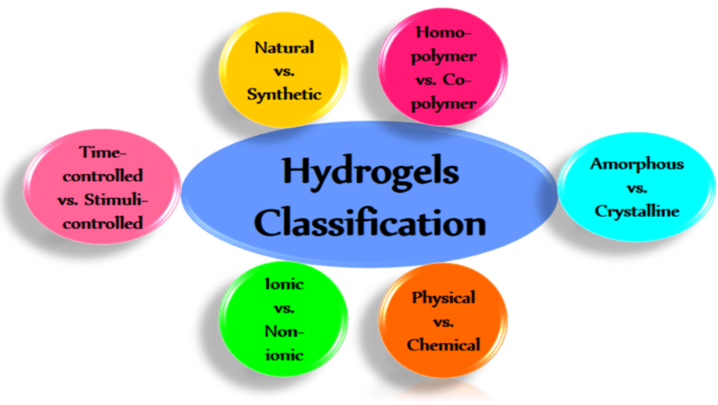


***Figure1**: Hydrogel Classification*

Hydrogels application and various administrative pathways

Hydrogels might be administered through several ways as medication delivery methods.

Oral route

The most popular, ideal, and medication approach is patient-compliant Oral administration is using administration. Co-polymer Because hydrogel networks improve oral absorption and bioavailability, they make an ideal drug delivery medium.

Because of their muco-adhesive properties, which might extend Hydrogels are thought to be effective at releasing and absorbing medications. Safe oral medication delivery systems. Hydrogels offer an additional benefit as oral drug delivery systems: they can shield the drug within enzymatic breakdown.[11] Drug delivery via oral hydrogels is the main area of research.[12]

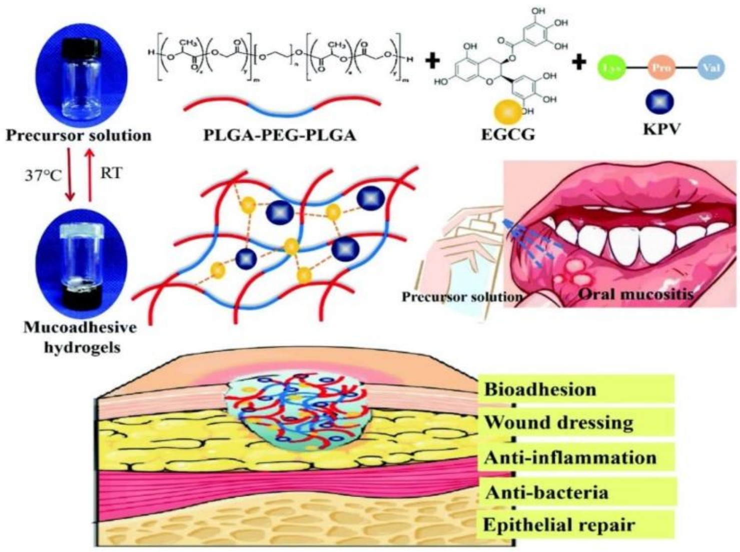


Figure 2: *Oral route*

Parenteral routes

Most favoured mode of management for many medications, including peptide along with protein, is intravenously. Parenteral drugs distribution might be accomplished through the use of hydrogels as mechanisms for regulated medication delivery. It is possible to prevent enzymatic breakdown of drugs, released more slowly, have a longer half-life, be more bioavailable, require fewer doses to be administered, and result in higher patient compliance when hydrogels are utilised.

Temperature sensitivity is a common characteristic of injectable hydrogels, which causes them to gel at body temperature and become solid at room temperature. medication release can continue, and the bioavailability of drugs can be enhanced by way of the gelation process. In parenteral drug delivery systems, Hydrogels based on poloxamers are the most common widely utilised heat-sensitive hydrogels; nevertheless, their inability to degrade biologically is a drawback.[13]

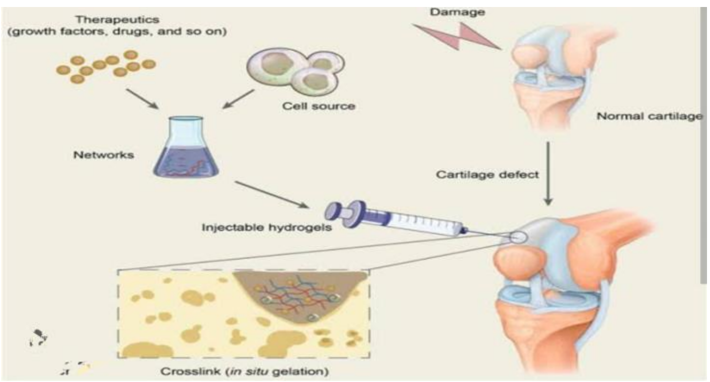


Figure 3: *Parenteral route*

Nasal routes

The advantages of nasal medication delivery include good patient compliance and the potential to boost drug bioavailability by preventing the hepatic first pass impact. Nevertheless, there are certain drawbacks to this delivery method as well, such as mucosal turnover leading to a brief nasal residency period and barrier action that prevents macromolecules from being absorbed through mucosal membranes. Mucoadhesive, viscoelastic, and biocompatible hydrogels like chitosan hydrogels are highly regarded as cutting-edge nasal delivery systems that could extend the amount of time that active drugs are loaded and remain in the nasal cavity. When heated to body temperature, the majority of polymers used in nasal delivery systems can gel at the site of action due to their temperature sensitivity.[14]

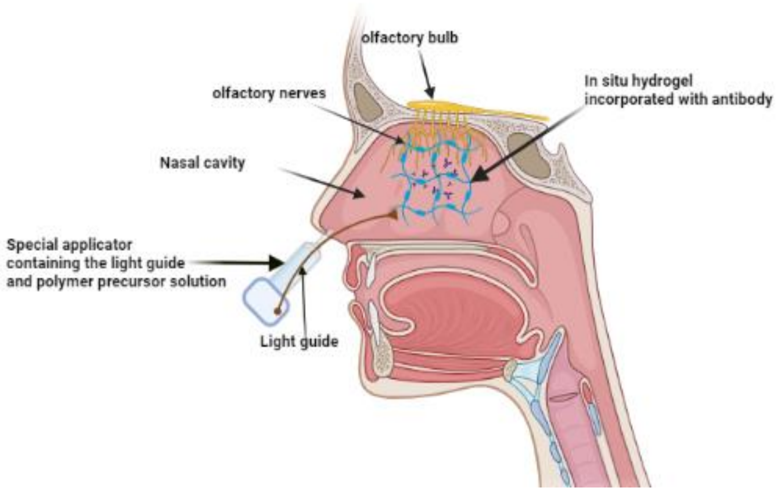
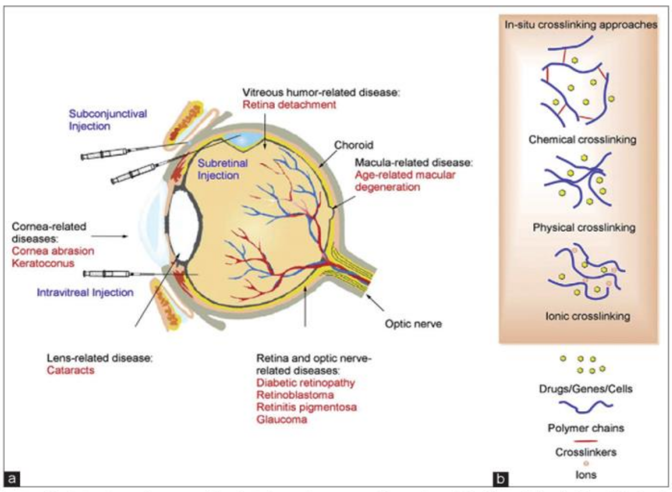


Figure 4: *Nasal routes*

Ocular routes

Drops are a frequent topical administration method for drugs intended for the eyes, however they are not very effective and can have systemic adverse effects. Merely 5 percent of the incorporated medicine may possibly reach The tissue inside the eye; however, around 95 percent would disappear because of a tear draining. In addition, drugs have a very limited half-life in the eyes. Consequently, it would be ideal to develop novel drug delivery systems that extend the duration of medication residence, decrease drug loss, and minimise systemic side effects. As ocular medication delivery systems that use the potential to improve medication bioavailability and residence time, contact lenses attracted the attention of numerous researchers. Drug delivery devices for the eyes were commonly assumed to be hydrogen contact lenses due to their biocompatibility and transparency.

In this situation, drug molecules could be evenly dispersed throughout hydrogel matrices (such as HEMA polymers); yet, this method is limited to hydrophilic medicines and could lead to quick drug release.[15] To solve this problem, pHEMA hydrogels could be fortified with hydrophobic or ionic monomers to enhance drug loading capacity, control drug release rate, and improve drug-hydrogel interaction.[16]



b) Anatomical structure of an eye with related eye disease and formation of *in situ* gelation in injectable hydroge

Figure 5: *Ocular routes*

Topical routes

One of the most popular methods of administering medication to minimise side effects and target specific sites for high doses of the substance is topical distribution. Because of their minimal potential for toxicity and prolonged drug release, hydrogels are considered suitable carriers for topical medicine administration. Because of their ability to swell and hydrate, hydrogels also offer the advantages of being soft, biocompatible, thus containing a significant amount of water, which can mimic the characteristics of living tissues and avoid pain for enclosed tissues.[17]

Brain delivery

The primary problem of getting medication to the cerebral cortex, which is still challenging, is the blood-brain barrier. Although there is a chance of infection and damage to brain tissue, local medicine administration through implants inside the brain is an option. Another technique for brain local administration is epi-cortical distribution, which distributes the medication straight into the brain using hydrogels with minimal tissue injury.[18]

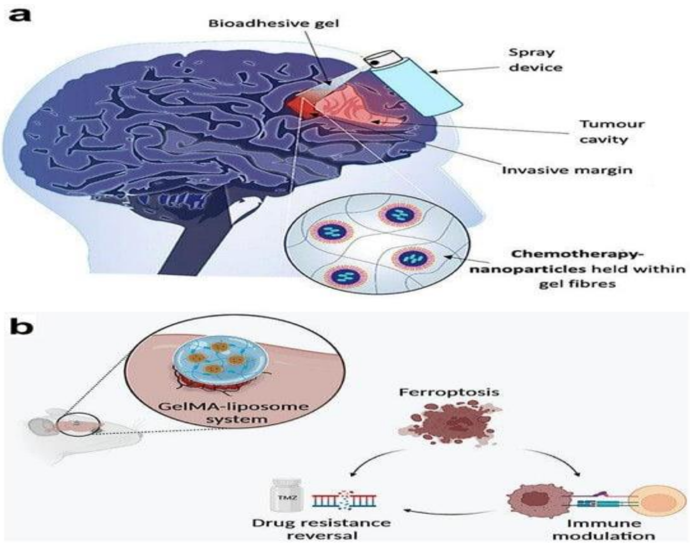


Figure 6: *Brain delivery*

Tissue engineering

The matrices outside of tissues are comparable to hydrogels, which encourage cell division, release incorporated growth factors gradually, and cause no discomfort to the surrounding tissues. These are only a few of the many benefits of hydrogels for tissue engineering applications. Compared to premade hydrogels, another type of traditional scaffold, injectable hydrogels are preferable because they are easier to handle, penetrate tissues more deeply, conform to margins better, and need less invasive procedures.[19] Another promising technological option to address the issues facing tissue engineering today is micro engineered hydrogels.[20]

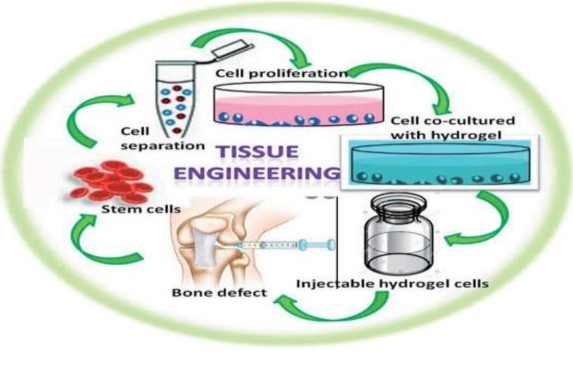


Figure 7: *Tissue engineering*

Gene delivery

Gene delivery via hydrogel scaffolding refers to the transfer of DNA or RNA with the aim of genetic alteration. Hydrogels may increase gene therapy's efficacy, particularly in the treatment of cancer. Lethal genes or siRNA would be incorporated in hydrogel scaffolds for cancer therapy, promoting the apoptosis of malignant cells The limited ability to load genes and the rapid release of enclosed genes are two disadvantages of hydrogel-based gene delivery. Numerous techniques have been explored to get over these restrictions, such as encasing DNA or RNA in a hydrogel scaffold after they condense in nanoparticle systems [21]

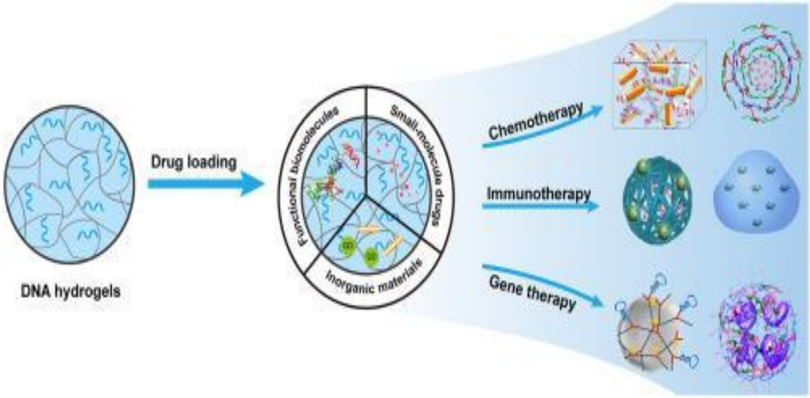


Figure 8: *Gene delivery*

Sr. No.	Scientific name	Family	Local identity	Active parts.
1	*Anacardium occidentale*	Anacardiaceae	Cashew	Cashew apple bagasse
2	*Moringa oleifera*	Moringaceae	Moringa	Leaves, seeds
3	*Bambusa vulgaris*	Poaceae	Bamboo	Leaves, steam, roots
4	*Ocimum tenuiflorum*	Lamiaceae	Tulsi	Leaves
5	*Eupatorium glutinosum lam*	Asteraceae	Matico	Leaves
6	*Pisum sativum*	Fabaceae	Pea	Pea seeds
7	*Solanum tuberosum*	Solanaceae	Potato	Peels
8	*Cinnamomum verum*	Lauraceae	Cinnamon	Bark
9	*Trigonella foenumgreacum*	Fabaceae	Fenugreek	Seeds
10	*Astragalus gummifer*	Leguminosae	Tragacanth	Steam
11	*Aloe barbadensis*	Liliaceae	Aloe Vera	Aloe Vera gel, Leaves
12	*Camellia sinensis*	Theaceae	Green tea	Green tea plant extract
13	*Zingiber officinale roscoe*	Zingiberaceae	Ginger	Steam, roots

14	*Luffa aegyptiaca*	Cucurbitaceae	Sponge gourd	Leaves
15	*Glycine max*	Fabaceae	Soy	Seed

Table 1: *Plants and their active Constituents used for preparation of Hydrogels*

Anacardium occidentale

Anacardium occidentale L., the cashew tree, is a native fruit tree that is widely cultivated in northeast Brazil. It is beneficial to produce its nuts and pseudo fruit, and it can be used to remove cashew gum (CG) by repeatedly cutting the trunk and branches. Chemical and pharmaceutical industries use CG because of its hydrophilic nature, low cost, biocompatibility, biodegradability, and flexibility in chemical modification. Producing biodegradable hydrogels from renewable natural materials is made possible by the abundance and simplicity of CG.A form of hydrogel known as cashew-based hydrogel is created with ingredients that come from cashew nutshell liquid (CNSL) or cashew nut byproducts.[22]

Because their bodies can hold large amounts of water, three-dimensional polymeric networks called hydrogels are useful in biomedicine, agriculture, and wastewater treatment. Hydrogels made from cashews are an example of the expanding trend of utilising natural, renewable resources to create biodegradable and sustainable productsOwing to the antibacterial qualities of CNSL components, biomedical applications in wound dressings are possible. drug delivery methods in which the hydrogel acts as a vehicle for the release of the drug under control. Agriculture to improve water retention in arid circumstances by acting as soil conditioners to hold onto moisture. Adsorbents for water treatment that remove organic contaminants and heavy metals while utilising the phenolic groups found in CNSL to improve binding. Because the hydrogel is biocompatible, packaging materials can be edible or biodegradable. benefits Resilience Hydrogels made from cashews are environmentally friendly because they use agricultural waste products. Degradability in a biological sense Hydrogels derived from cashews have a lower environmental impact than synthetic ones since they decompose naturally. Properties that Resist Microbes For usage in biomedical applications, CNSL components offer built-in bacterial resistance.[23]

Figure 9: *Anacardium occidentale*

Moringa oleifera

Moringa oleifera, is a significant medicinal plant in the genus *Moringaceae*. It is mostly found in North-Western India's sub-Himalayan region and is well-known for its nutritive and therapeutic properties, which are used in Ayurvedic texts to prevent, reduce, or treat a variety of illnesses. This

plant's seeds, fruits, leaves, and roots have historically been used to treat helminthic infections, skin infections, ulcers, abdominal tumours, prostate issues, scurvy, hysteria, and paralytic attacks
Extracts from Moringa oleifera Bioactive substances like anti-inflammatory, antioxidant, and antimicrobial peptides can be included into the hydrogel matrix by using moringa leaves, seeds, or bark. Hydrogel's Polymer Base Common hydrophilic polymers like alginate from sodium, Chitosan, or polyvinyl alcohol, also known as PVA, usually form the gel structure. These polymers' ability to absorb and retain large amounts of water gives the hydrogel its unique swelling properties.
Moringa-Based Hydrogel Extraction Solvent extraction or maceration are the initial steps in the preparation of Moringa extracts, such as leaf or seed extracts. Within Tissue Engineering Given that Moringa is both biocompatible and bioactive, hydrogels of this kind might be investigated for use as scaffolding in tissue engineering, which could help promote tissue healing and cell proliferation.[24]

Figure 10: *Moringa oleifera*

Bambusa vulgaris

Bamboo, a biomass material, has a brief growth cycle and performs exceptionally well. The world's richest source of bamboo resources is China, referred to as the "Kingdom of Bamboo."[25,26] Bamboo has been widely employed in the creation of functional composites and polymer reinforcement due to its remarkable qualities of low density, superior mechanical strength, and biodegradability.[27]Bamboo's chemical composition is similar to that of other plants, like wood, and includes added sugars, lipids, proteins, and inorganic salts in addition to cellulose, hemicellulose, and lignin. Twenty percent of bamboo is made up of lignin, and forty percent is composed of cellulose.[28] The two primary structural and compositional components of bamboo are parenchyma cells and sclerenchyma fibres. Eighty percent of the processing wastes from bamboo that are produced in China each year are made of parenchyma cells, proving that parenchyma cells are a great starting point for making nanocellulose.[29,30] Bamboo parenchyma has stronger cells, more microfibril perspectives, less lignification, and easier wall layer peeling than timber, all of these promote cell wall dispersion.[27,31]Because bamboo contains a high concentration of cellulose, many methods have been employed to manufacture cellulose-based hydrogels, demonstrating the enormous potential of bamboo in this regard. The main component of cellulose is dehydrated glucose, or β-D-glucopyranosyl. $(C_6H_{10}O_5)_n$ is the formula for a simple molecule. Hydrogels based on cellulose can be made by using cellulose and crosslinking agents. [32,33]

Figure 11: *Bambusa vulgaris*

Ocimum sanctum

Holy basil, tulsi, or just tulsi is another name for *Ocimum sanctum*, a fragrant perennial herb of the Lamiaceae family Antistress, hepatoprotective, hypotensive, hypolipidemic, cancer-fighting, antiasthma tic, antiemetic, sedative, antidiabetic, and antifertility are among the traditional uses of Tulsi. The herb's leaves, blooms, stem, root, and seeds are also used. An water-based infusion of tulsi has been used to treat numerous ailments, including convulsions, arthritis, bronchitis, and fever.[34] Although ursolic acid, carvacrol (5-isopropyl-2-methylphenol), linalool (3,7-dimethylocta-1,6-dien-3-ol), limatrol, caryophyllene (4,11,11-trimethyl), eugenol (1-hydroxy-2-methoxy-4-allylbenzene), eugenol (also called eugenic acid), Polysaccharides and xylose are the compounds that make up sugars.[35]

The objective of the current study was to assess the anti-inflammatory properties of *Ocimum sanctum* leaves in both their natural state as well as using a hydrogel formulation. Because of their traditional applications and chemical composition, which has been demonstrated in readily available literature to be advantageous for inflammation. conditions in hydrogel formation, these plant leaves were chosen. Tulsi, which is high in antioxidants, helps combat oxidative stress. This can be particularly useful for materials used for skin treatments or to protect the tissues and cells from damage. Hydrogels are widely used as drug delivery systems due to their biocompatibility and ability to control the release of helpful substances. These hydrogels can be used to boost the therapeutic properties of other drugs or to deliver the bioactive compounds in tulsi.[36]

Figure 12: *Ocimum sanctum*

Eupatorium glutinosum lam

Many regions of the world have used the genus Eupatorium of the Asteraceae family in traditional medicine. [37,38] In Ecuador, people use the plant *Eupatorium glutinosum Lam*. for medical purposes since it has antibacterial and anti-inflammatory properties.[39]Matiko is the colloquial term.[40]Roughly speaking, this plant can grow up to 3,000 metres above sea level (masl). E.

glutinosum has reportedly been used to treat stomach ulcers, migraines, and diarrhoea. Research on the Eupatorium genus shows that alkaloids, terpenoids, lactones, flavonoids, and their derivatives are present.[41]

Astringent, antirheumatic, and antibacterial properties may be attributed to this kind of secondary metabolite.[42] Particularly in the pharmaceutical and medical industries, it can provide innovative uses when paired with hydrogel technology. Suitable for skin care, medication delivery, and wound dressings, hydrogels are extremely absorbent polymers that have a large capacity to store water.

A hydrogel based on Eupatorium glutinosum may be able to take advantage of the bioactive components of the plant to promote wound healing, offer antimicrobial defence, or precisely administer medicinal medicines. In order to care for wounds or release the plant's chemicals gradually, the hydrogel would function as a carrier, keeping the surrounding moist.[43]

Figure13: *Eupatorium glutinosum lam*

Pisum sativum

Because of its extensive composition of bioactive compounds, such as proteins, carbohydrates, and fiber, which give to its gel-forming properties, *pisum sativum,* or pea, is becoming more and more popular in the creation of herbal hydrogels. Pea extract is a useful component for applying to hydrogels intended for moisturising or skin-healing applications because of its anti-inflammatory, antioxidant, and wound-healing qualities. Pisum sativum is a great option for producing stable, potent hydrogels as well in topical formulations because of these qualities as well as the fact that it is non-toxic and biocompatible.

The proteins in Pisum sativum act as natural emulsifiers and stabilisers, improving the consistency and texture of hydrogels. Furthermore, its bioactive compounds, including flavonoids and polyphenols, exhibit antimicrobial activity, enhancing the functionality of hydrogels designed for wound care by protecting the application site from infection. In addition, the fibre and starch content of peas contribute to the structural integrity of hydrogels, helping to control the release of active ingredients over time.

Studies have demonstrated the effective incorporation of Pisum sativum in hydrogel formulations for both pharmaceutical and cosmetic purposes. For instance, hydrogels containing pea extract have shown promise in delivering herbal actives to the skin in a controlled manner, with enhanced moisture retention and skin regeneration properties, making it suitable for burns, ulcers, and other skin conditions.

Vitamins like C and E are also abundant in *pisum sativum* extract, which strengthens its ability to heal wounds and protect skin. It is appropriate for sensitive or damaged skin because of its anti-inflammatory properties, which help to lessen redness, swelling, and irritation. By encouraging skin repair and protection, Pisum sativum not only improves the gel's physical qualities but also adds to its the effectiveness of treatment in the creation of herbal hydrogels.[44,45,46,47]

Figure 14: *Pisum sativum*

Solanum tuberosum

A novel substance called potato-based hydrogel is mostly made of potato starch. Large volumes of water can be absorbed and retained by networks of polymer chains, which make up hydrogels. Potato starch is abundant and sustainable, thus hydrogels made of it have become more popular in a number of industries, particularly biomedical, agricultural, and environmental applications. Potato starch has a strong resistance to pressure-induced gelation, as evidenced by previous studies.

Therefore, very high-pressure levels are needed to fully gelatinized potato starch–water suspensions. However, since potato starch is used extensively in the food industry for coating, blending, bulking, thickening, and, more recently, gel-hardening, a better understanding of its behaviour during HHP assisted gelation would be crucial for the industrial use of HHP hydrogels in the future. Potato starch is environmentally beneficial because it spontaneously biodegrades. Not harmful safe for use in cosmetics, food packaging, and medical applications. increased absorption of water beneficial in moisturising applications like soil conditioners and treatments for wounds.

Both economical and renewable Because they are affordable and widely farmed, potatoes have a sustainable use.In dressings for wounds These hydrogels can lessen the chance of infection, encourage healing, and keep wounds moist. Systems for delivering drugs. Drugs can be released gradually using hydrogels, which enhances therapeutic results. Farming Soil conditioners They help the soil hold onto water better, which encourages the growth of plants in arid environments.

During germination, seed coating aids in keeping nutrients and moisture around seeds. Packing films and coatings that are edible are used to extend the shelf life of food packaging. Eco-friendly packing materials naturally disintegrate, cutting down on plastic waste. Cosmetics Because of their moisturising qualities, they are used in moisturisers, masks, and other personal care products. [48,49,50,51]

Figure 15: *Solanum tuberosum*

Cinnamomum verum

In the Lauraceae family, *Cinnamomum verum* J.S. Presl belongs. The hydrogel matrix of cinnamon-based hydrogels is infused with chemicals or extracts from cinnamon, making them innovative biomaterials. Among the main ingredients that come from the volatile oil of cinnamon bark are trans-cinnamaldehyde, linalool, and eugenol. These components are responsible for their analgesic and anti-inflammatory qualities. Aside from its anti-inflammatory and anti-diabetic effects, cinnamon also possesses antiseptic, anticoagulant, analgesic, and antioxidant qualities.

It can help prevent pimples and blackheads from developing and boost immunity. Due to these plants' analgesic and anti-inflammatory properties, topical semi-solid dose forms are offered separately. The primary edible and therapeutic components of cinnamon are taken from its bark, branches, and leaves, and are known as cinnamon oil (CMO). CMO has many potentials uses as a natural component in the meals, beauty products, biomedical science, perfume, and pesticide industries due to its remarkable aromatic flavor, insect-repelling properties, antioxidant impact, and superior antibacterial activity. The findings of the CMO antibacterial test demonstrated that not only could CMO readily prevent the growth of mould and yeast, but it was also able to inhibit the growth of bacteria, demonstrating its broad-spectrum antibacterial action and potential use as a natural antibacterial agent. Healing Wounds Faster healing and infection prevention are made possible by the antibacterial and anti-inflammatory qualities.

Medication Administration Methods Cinnamon components offer extra therapeutic effects when used with hydrogels to encapsulate medicines. Engineering of Tissue supports new tissue formation, particularly skin regeneration. coatings with antimicrobial properties Surfaces can be treated with these hydrogels to stop the growth of biofilms and microbiological contamination. [52,53,54,55]

Figure16: *Cinnamomum verum*

Trigonella foenumgreacum

The herb fen (Trigonella foenum-graecum, Leguminosae), a type of legume that is also referred to as "methi," is the most promising of the different polysaccharide-based gums because of its advantageous properties. It is an occurring naturally polymer composed of one d-galactose unit connected to a 1,4-the sugar mannose linear chain by a 1,6-bond. Apart from having a 1:1 ratio of d-mannose to d-galactose and a larger concentration of hydroxyl groups (-OH), which give it a better affinity for water, fenugreek and guar gum are structurally similar.

Due to the previously mentioned characteristics, fenugreek can be utilised as a natural Hydrogels derived from fenugreek are novel materials that have potential uses in tissue engineering, medication delivery, wound healing, and cosmetics. The hydrogel's production and characteristics are significantly influenced by polysaccharides like galactomannans, which are abundant in fenugreek (*Trigonella foenum-graecum*) seeds.

High Capacity of Swelling absorbs a lot of biological fluids or water, which helps with wound healing. Biocompatible and biodegradable: Safe for use in medicine and not harmful to health. Antimicrobial Intensity Fenugreek is good for wound treatment since it has modest antibacterial and antioxidant qualities. Sensitivity to pH sensitive to pH and temperature changes in the environment, which is helpful for tailored drug administration.

Within the Medication Administration System Drugs can be put into fenugreek hydrogels for targeted and sustained release, particularly in gastrointestinal disorders where pH fluctuation is a factor. Their inherent makeup reduces side effects and toxicity. Healing of Wounds The hydrogel's capacity to hold moisture encourages quicker healing and guards against infections. Fenugreek's antioxidant content may lessen inflammation. Tissue Design Because of their biocompatibility and porous nature, they are utilised as scaffolds to promote tissue regeneration and cell proliferation. Makeup used for skin hydration and anti-aging benefits in face masks, serums, and moisturising creams. [56,57]

Figure17: *Trigonella foenumgreacum*

Astragalus gummifer

The *gum tragacanth* (GumT), which is derived from various astragalus plant species, is one of the less expensive polysaccharides among the numerous others. This polysaccharide is stable, non-toxic, and biocompatible. It is composed of two unique parts: bassorin, which makes up between 25 and 50 percent of the polysaccharide, and tragacanth, which is extremely water soluble and makes up between 50 and 75 percent.

With its primary and secondary groups (hydroxyl and carboxylic), gum tragacanth is an arabinogalactan gum that provides ideal locations for linking different functions. Its adhesive qualities, lack of toxicity, antioxidant activity, non-carcinogenicity, biodegradability, and non-mutagenicity have also shown it to be more beneficial in a variety of different sectors. Many hydrogel composites based on natural gum have been researched for the remediation of water pollution, particularly in the adsorptive removal of organic and inorganic forms of contaminants from water utilising a hydrogel nanocomposite based on tragacanth gum and including $CaCO3$ nanoparticles.

Sahraei and colleagues created gum tragacanth hydrogel magnetic beads that were modified with graphene oxide and polyvinyl alcohol. These beads have been used to selectively adsorb colours and metal ions. Mandal and Ray created an IPN hydrogel with good adsorptive properties for synthetic dyes in a different investigation. Hydrogels have the ability to release medications in a regulated manner in biomedical field drug delivery systems, especially for pH-sensitive locations like as the gastrointestinal tract.

Bandages for Wounds In addition to preventing bacterial infections, the gel keeps the area hydrated and aids in healing. Engineering of Tissue scaffolds that promote the growth and regeneration of cells. Makeup and Personal Hygiene found to stabilise and add moisture to compositions in lotions, creams, and serums. food sector used in products such as syrups, sauces, and dressings as a thickening agent and stabiliser. Hydrogels derived from environmental tragacantha can be used in agriculture or water treatment to help soil retain moisture. [58,59,60]

Figure 18: *Astragalus gummifer*

Aloe vera

Aloe vera, which is part of the Liliaceae family of medicinal plants, is used extensively in food products, cosmetics, and pharmaceuticals. The global aloe vera hydrogel market was estimated to be worth $337.7 million in 2022, and it is expected to grow at a CAGR (compound annual growth rate) of 7.8% from 2022 to 2032, which is higher than the predicted CAGR of about 6% for the 2017–2022 period. Aloe vera's arrangement, which is primarily composed of liquid (>98%) in the mucilaginous gel and less than 2% of vitamins, minerals, enzymes, and polysaccharides (like hemicellulose, cellulose, and cellulose mannose derivatives, pectin, glucomannan, and acemannan). Hydrogels derived from aloe vera are extensively researched for a variety of uses because of their superior biocompatibility, calming qualities, and moisture-retention capacity. These hydrogels, which have special benefits in the sectors of biomedicine, cosmetics, and wound care, are created by mixing aloe vera gel or extract into a polymeric matrix. Gels Made with Aloe Vera Wound Healing creates a moist environment that speeds up the healing of wounds. applied to surgical dressings, ulcers, and burn treatments.

Medication Administration Methods For topical or transdermal applications, aloe vera hydrogels can contain and release medications in a regulated way. Cosmetics & Skincare Items found to hydrate and soothe the skin in sunburn recovery products, moisturisers, and face masks. Because aloe vera has antioxidant qualities, it is used in anti-aging lotions. Engineering of Tissue Aloe vera hydrogels can be used to regenerate skin and other tissues because they function as scaffolds for cell growth. [61,62,63,64,65,66,67,68]

Figure 19: *Aloe Vera*

Camellia sinensis

Hydrogels based on green tea are biomaterials that contain ingredients that come from tea, including catechins, especially epigallocatechin gallate (EGCG). Because of their anti-inflammatory, antibacterial, and antioxidant qualities, these hydrogels are drawing interest in biological and environmental applications. An outline of their salient characteristics, synthesis, and uses is provided below. Model nutrient selection was based on green tea polyphenols (GTP), a naturally occurring polyphenolic component derived from tea. The synthesis of salecan/TMC PEC hydrogels as nutrient transporters has never been studied before, as far as we are aware.

They underwent thorough investigations into their rheological properties, pore shape, thermal stability, and chemical makeup. Additional variables that were thought to have an impact on the intake of water were the salecan/TMC ratios. We postulated that, under gastric settings, GTP could be purposely released from the hydrogels by utilising pH as a trigger, but that it could also be kept within after intestinal conditions. Accordingly, a thorough investigation of the hydrogels' GTP release in intestinal and gastric pH media was conducted. Additionally, the power law equation was utilised to ascertain the various release mechanism kinds.

Epigallocatechin gallate (EGCG), a polyphenol found in green tea, has antioxidant and antibacterial qualities. gel-forming Polymers: These could include: Natural: alginate, chitosan, Gelatin, or hyaluronic acid. Synthetic materials include polyvinyl alcohol (PVA) and polyethylene glycol (PEG). When Wounds Heal The hydrogels can hasten the healing process because EGCG has antibacterial and anti-inflammatory qualities. Inhibits the growth of microorganisms at the location of the lesion, preventing infections. Medication Distribution Methods Drugs or other active compounds can be enclosed in these hydrogels for regulated release. beneficial for anti-cancer treatments because EGCG has demonstrated anti-cancer qualities. Tissue Design creates an environment that is biocompatible for the growth and regeneration of cells. may aid in the restoration of skin, bone, or cartilage. Antioxidant Films and Coatings Green tea-based hydrogels are applied as protective coatings to stop products in food packaging or cosmetics from oxidatively deteriorating. Applications in the Environment Adsorbents used in water filtration that use interactions between polyphenols to absorb heavy metals or dyes. [69,70,71]

Figure 20: *Camellia sinensis*

Zingiber officinale roscoe

Because of its purported antiviral, anti-diabetic medications, antioxidant, and anti-inflammatory properties, *Zingiber officinale Roscoe*, commonly known as ginger, is used as a spice and in traditional medicine. Ginger is rich in starch, cellulose and hemicellulose, but it also contains several bioactive chemical families, such as zingiberene, gingerols, and shogaols. Ginger the essential oil concentration (GEO) has significant antioxidant, antifungal, and antibacterial qualities. Geranial, α-zingiberene, (E, E)-α-farnesene, neral, and ar-curcumene make up the majority of its composition. Even though in vitro and in vivo experiments have confirmed the pharmacological properties, fewer studies have focused on using its nanofibers to create bio nanocomposites, films, and aerogels.

Thus far, there has been no research done on the possible application of ginger and its natural constituents for wound dressing applications, including the extraction of nanofibers and their usage in the creation of hydrogels that are solely based on ginger. Regarding Injury Recovery Ginger has anti-inflammatory and antibacterial properties that promote wound healing. Tissue regeneration is aided by hydrogels, which keep the surroundings wet.

Within the Delivery of Drugs With regulated release mechanisms, ginger hydrogels can be used as delivery systems for various medications. Oral formulations for gastrointestinal benefits or transdermal patches for targeted pain alleviation are examples of applications. Cosmetics and Skincare Because ginger has antioxidants that fight inflammation and ageing indications, it's used in face masks and moisturising creams. Hydrogels enhance skin hydration and facilitate the active substances' absorption.

These hydrogels have potential applications in regenerative medicine, such as wound scaffolding and cartilage regeneration, due to the anti-inflammatory qualities of ginger. Cancer-fighting Medicine Hydrogel-based ginger extracts have demonstrated promise in medication formulations intended to target cancer cells and reduce inflammation. [72,73,74,75,76]

Figure 21: *Zingiber officinale roscoe*

Luffa aegyptiaca

The scientific name for the loofah, often called the *sponge gourd*, is *Luffa cylindrica* (LC), and it has a structure made of ligneous fibre netting. A natural mat is created by the multidirectional arrangement of the fibrous cords. Based on recent research, the loofah sponge has proven to be an effective carrier for chondrogenic regeneration and bio-immobilization, where cellulose/hemicellulose and lignin are the primary chemical components.

PHBV is a widely recognized microbial copolymer that is frequently used for scaffolds in tissue engineering because of its biocompatible and biodegradable properties as well as its spinnability in wet electrospinning. Additionally, it enhances the mechanical and thermal properties of natural polymers. Gardenia fruits are processed using a modern microbiological technique to extract genipin, a crystalline and well-defined chemical component. Being a reagent for bifunctional crosslinking that is soluble in water, it reacts quickly with chitosan and other proteins or amines to create fluorescent hydrogels that are blue in colour.

In the current investigation, it is favoured as a crosslinking agent. When treating wounds Luffa hydrogels are skin-friendly, biodegradable, and capable of absorbing fluids, fostering healing, and preventing infection. Engineering of tissues the porous structure is a promising option for regenerative medicine since it can act as a scaffold for cell development and nutrient diffusion.

methods for delivering drugs can be released from the hydrogel gradually and under control. purifying of water, it can be used as an adsorbent to draw impurities like colours and heavy metals out of water. Farming serves as a soil supplement to help plants grow more quickly and retain moisture. [77,78]

Figure 22**:** *Luffa aegyptiaca*

Glycine max

Biomaterials with biocompatibility, biodegradability, and environmental friendliness are soy-based hydrogels, which are generated from soy. Utilising soy resources into hydrogels—networks of polymers with a high water-holding capacity—can enhance their performance and optimise the release of active ingredients, such as fertilisers or medications, or provide environmental sustainability.

Figure 23**:** *Glycine max*

Soy Protein Isolate (SPI): Soy protein that has been refined and contains cross linking functional groups. Soybean Oil and Its Byproducts These can be changed to make networks that are polymerizable. Polysaccharides—the kind found in soy—assist in the formation of gels with a high-water retention. Crosslinkers: Substances that promote network development include glutaraldehyde and enzymatic treatments.

Agriculture used to enhance soil moisture retention and manage pesticide or fertiliser release. Applications of Biomedicine in Healing Wounds Soy hydrogels create an environment that is wet and encourage cell proliferation. delivery of drugs able to encapsulate medications for long-term, continuous release. Engineering of Tissue acts as scaffolding to encourage tissue regeneration and cell proliferation by imitating extracellular matrices. Uses in the Environment using adsorption to remove contaminants or heavy metals from water. in industrial applications as biodegradable substitutes for artificial hydrogels. [79,80,81,82,83]

CONCLUSION

Hydrogels have emerged as a promising delivery system for herbal medicines due to their biocompatibility, tunable properties, and ability to provide controlled release. These polymeric networks can enhance the stability, bioavailability, and therapeutic efficacy of plant-based compounds. Additionally, hydrogels offer protection from environmental degradation, improving the sustained release and targeted delivery of herbal actives. With the growing interest in natural therapies, hydrogel systems can bridge the gap between traditional herbal remedies and modern pharmaceutical technologies. However, further research is required to optimise formulations, address regulatory challenges, and ensure safety through clinical studies. The integration of hydrogels in herbal medicine delivery holds great potential for advancing natural therapeutic

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