OPINION

Recent progress of herbal medicine nanofibers

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ABSTRACT

Herbal medicine has a long history of being medically effective, with low toxicity, side effects, and high biocompatibility. However, the bioavailability of raw herb extracts and bioactive components is minimal due to their low water solubility. To circumvent the solubility concerns, electrospinning technology can provide a delivery option. Electrospun fibres have a high specific surface area, a high porosity, good mechanical strength, and flexible architectures.

Various natural and manmade polymer-bound fibres can simulate extracellular matrix usage in a variety of medical sectors at the same time. This research examines the evolution of electrospinning technology and the polymers used to incorporate herbal medicine into electrospun nanofibers.

Key Words: *Herbal medicine; Biopolymers; Nanofibers; Drug delivery*

INTRODUCTION

Herbs are commonly utilized in traditional remedies such as Traditional Chinese Medicine (TCM), Indian medicine (Ayurveda, Unani, and Xida), Japanese Kampo, and Korean medicine, among others. It's been around for hundreds, if not thousands, of years .In contrast to synthetic pharmaceuticals' "one ailment, one target, and one medication" way of administration and therapy, herbal medicine comprises a range of components that can have a multi-target synergistic impact.

Traditional herbal remedies' bioactive components primarily include phenols, saponins, flavonoids, tannins, terpenoids, and alkaloids. They possess antibacterial, antiviral, anti-inflammatory, antioxidant, anti-tumor, analgesic, immune-regulating, and tissue regeneration properties. Stretching , self-assembly , phase separation , template synthesis , physical and chemical vapors deposition , electrochemical deposition , laser ablation, freeze-drying , solvent casting, solution blowing , dry-wet spinning , force spinning , and electrospinning are currently used in the manufacture of nanofibers. Electrospinning is a type of Electro Hydro Dynamic Atomization (EHDA).Its procedure is simple, low-cost, efficient, and reproducible, and it accepts a wide range of raw materials. The use of synthetic and natural polymer materials is crucial throughout the production process.

They determine the activity and mode of delivery of herbal medications. The majority of natural polymers are biocompatible, nontoxic, biodegradable, and adaptable. The extracellular matrix (ECM)-like features that stimulate cell growth and adherence demonstrate its versatility. It may also be utilized to build scaffolds to provide an optimum environment for cell growth and proliferation.

Some biological synthetic polymers have been examined for their consistent quality, flexibility in synthesis, processing, and modification, and strong mechanical stability in vivo in order to address these difficulties. These biological synthetic polymers, on the other hand, are "coated" to assure their controllability and target delivery capabilities.

Encapsulating herbal medicine in electro spun nanofibers

Herbal medication cannot be properly integrated into nanofibers because the solution's viscosity is too high for the electrospinning process.

SYNTHESIS OF POLYMER LOADED WITH HERBAL MEDICINE

According to functional applications, synthetic polymers utilized in the electrospinning of herbal medicines are divided into hydrophobic and hydrophilic classes. They are biocompatible as well as biodegradable. Poly Capro Lactone (PCL), Poly Lactic acid (PLA), Poly Urethane (PU), Poly Lactic acid Glycolic Acid copolymer (PLGA), and Poly (L-lactic Acid) PLLA are the most widely utilized hydrophobic polymers.

Hydrophobicity

Poly Capro Lactone (PCL) and Poly Lactic Acid (PLA) are widely used with herbal medicine for the administration of wound dressings. Poly Capro Lactone (PCL) is semi-crystalline hydrophobic synthetic polyester. Poly Lactic Acid (PLA) is a starch and sugar-derived aliphatic polyester. As a result, it is seen as an ecologically acceptable alternative to petroleum-based polymers, and it shares many properties with thermoplastics.

These polymers' hydrophobic qualities have resulted in superior

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mechanical properties and a slow dissolving rate, which can facilitate long-term healing and a mild inflammatory response.

Researchers created a Poly (L-Lactic Acid) (PLLA) polymer because to the exceptional characteristics of PLA. It possesses good mechanical and biodegradable qualities, similar to polylactic acid, and is used in bone tissue applications. Simultaneously, incorporating herbal medication into electro spun PLLA fibers can increase hydrophilicity and osteoinductivity. According to Parvathi et al., PLLA nanofibers containing a high proportion of Cissus Quandrangularis (CQ) are hydrophilic and can trigger osteogenic differentiation of MSCs.

Hydrophilicity

Hydrophilic polymers offer high film-forming capabilities, a quick dissolution rate, and superior biological adhesion when compared to hydrophobic synthetic polymers. They are utilized to provide herbal medication, skin and wound treatment applications, and food packaging due to their adaptability. Poly Vinyl Alcohol (PVA) is a colorless and tasteless water-soluble semi-crystalline petroleum-based polymer. Poly Vinyl Pyrrolidone (PVP) is biocompatible and has good tensile characteristics. In addition to PVA and PVP polymers, Poly Ethylene Oxide (PEO) is a hydrophilic polymer that is frequently utilised as a drug carrier matrix. They may retain good moisture content, attach well to skin wounds, minimise inflammation, increase skin cell proliferation, and wound contraction without scarring.

Other herbal medicine polyester

In addition to typical synthetic polyesters, various copolymers, such as pH-sensitive polymers, higher thermoplastic polymers, and bacterial-derived synthetic polymers, have been employed in medical applications. Carbomer and Eudragit E100 (EE100) are pH-sensitive polymers. Eudragit E100 (EE100) is a low-swelling cationic copolymer comprising butyl methacrylate and methyl methacrylate. Juste et al. employed it as an oral delivery system for antibacterial Oregano Ethanolic Extract (OEE), represents the active ingredient release curve. Carbomer is a very hydrophilic polymer with linear swelling and varying viscosities at various pH levels.

HERBAL MEDICINE LOADED NATURAL POLYMER

The natural polymers utilised in electrospun herbal medicine may be split into two categories: polysaccharide and protein. The source polysaccharide is separated into animal polysaccharides, plant polysaccharides, algae polysaccharides, and bacteria source polysaccharides. Similarly, protein may be classified according to its key components and activities as collagen, silk fibroin, maize protein, and keratin.

Polysaccharides

1. Animal polysaccharide
   Animal polysaccharides being studied in the preparation of herbal medicine nanofibers include chitosan (CS) and Hyaluronic Acid (HA). After cellulose, CS (-1,4-glycosidic bond linearly connected glucosamine) is the second most prevalent natural cationic polysaccharide on the planet. It may be found in the shells of crustaceans, insects, and fungus like crabs and shrimps. It is a carbohydrate polymer (glycosaminoglycan) derived from natural chitin by alkaline heterogeneous deacelytation. The amount of N-acetylamino and d-glucosamine in cutaneous tissue varies depending on the degree of deacetylation. Because of its excellent absorption, low cost, biodegradability, immunostimulatory qualities, non-toxicity, antibacterial, anti-inflammatory, and remodelling properties, CS has been widely employed in biomedical applications.

2. Plant polysaccharide
   Plant polysaccharides, particularly cellulose, are also commonly employed in electrospun herbal remedies. As carriers, pectin and starch are also utilized. Cellulose is the most significant and abundant natural biopolymer in nature, as well as the major component of green plant cell walls. It is a thermally and mechanically stable linear isomorphic homopolymer of -(1-4)-glycosidic bond-linked D-an hydroglucan. The fast progress in the field of nanotechnology has opened up the potential of cellulose. In the electrospinning process, nanocellulose has a nanoscale size, which may be hundreds of nanometers, microns, or more.

Proteins

Protein is an amino acid that is required by the human body. This type of polymerization is biocompatible and comparable to human ECM. Simultaneously, loading bioactive compounds taken from herbal medicine can improve cell adhesion and proliferation, which is frequently employed in medical applications. Collagen production accounts for around 30% of an animal's body weight. It is the most essential protein in the body and the primary fibrin in the ECM, sustaining tissue and organ structure and regulating cell activity.

Collagen is also employed in the engineering of bone tissue. Zhang et al electrospun Poly Capro Lactone (PCL)/Poly Vinyl Pyrrolidone (PVP) nanofibers loaded with berberine (BER) to mineralized collagen (MC)/Ch itosan (CS) cast film to generate a double-layer film to assure bone regeneration and remodelling.

1. Gelatin is made by hydrolyzing animal collagen in an acidic or alkaline solution. It is also the most plentiful component of bone and skin. Its composition and biological properties are nearly identical to those of collagen. Gelatin is so physically and chemically comparable to the extracellular matrix ECM.Furthermore, gelatin has an amino acid sequence that is comparable to the Arg-Gly-Asp (RGD) sequence, which can increase cell adhesion and migration. Gelatin nanofibers are a suitable material for wound dressings due to their unique function. Yao et al. used a mixed gelatin prepared from freshwater fish skin collagen and hog collagen. On the one hand, fish gelatin can minimise expenses and some infectious illnesses, and on the other side, it has a relatively high thermal stability.

2. Silk Fibroin (SF) is one of the strongest and hardest biomaterials. It is a natural structural protein derived from silk worms. It is a key protein component comprised of a heavy (H) chain and a light (L) chain joined at the C-terminus by a disulfide bond. Silk fibroin is a promising contender for biomedical applications due to its versatility and low-cost manufacture. It offers unique biocompatibility and biodegradability, as well as low immunogenicity, anti-inflammatory properties, permeability, strong cell adhesion, and the ability to regulate the release of growth factors.

3. Zein is a hydrophobic plant protein (the major storage protein of maize) that is mostly made up of amino acids like leucine (20%), glutamic acid (21-26%), alanine (10%), and proline (10%). Corn protein is biodegradable, biocompatible, flexible, and has great microbiological resistance. It is also non-toxic and
4. storage protein of maize) that is mostly made up of amino acids like leucine (20%), glutamic acid (21-26%), alanine (10%), and proline (10%). Corn protein is biodegradable, biocompatible, flexible, and has great microbiological resistance. It is also non-toxic and antioxidant. As a possible matrix for skin regeneration, Rad et al. created PCL/Zein/GA nanocomposite scaffolds containing *Calendula officinalis* extract. *Calendula officinalis* contains several chemicals and has a wide range of benefits, including blood coagulation, anti-bacterial, anti-inflammatory, and free radical inhibition.

APPLICATIONS OF HERBAL MEDICINE

1. **Drug delivery system**
   Herbal Nano Medicine (HNM) delivery systems have become a popular study area in recent years because to their precise drug administration, reduced toxicity and increased activity, and potential to solve herb-related issues. To increase bioavailability, numerous medication delivery techniques are employed. Polymer nanoparticles , hydrogels , micelles , nanotubes , dendrimers , liposomes , and nanofibers are a few examples . Bioactive compounds are integrated into suitable nanocarriers to increase bioavailability and efficacy by lowering toxicity and allowing for prolonged drug release at target areas, as well as improving their physicochemical stability and solubility.
2. **Food packaging**
   People are becoming increasingly concerned about food safety as their standard of living improves, and consumers are becoming concerned about the negative effects of synthetic food additives and plastic packaging on human health. As a result, bio-based packaging for food preservation has long been a hot issue. Active nanofiber membranes are created in this field by combining antibacterial and antioxidant compounds with biopolymer materials to reduce environmental problems caused by microbial contamination and nondegradable materials, extend food shelf life, and meet health and environmental protection needs.
3. **Wound dressings**
   Wound dressings must have a skin-like structure, be bioactive, and be biodegradable . High swelling capacity, porosity, good water vapour permeability, maintaining a humid environment at the wound site, absorbing excess exudate from the wound, essentially non-adherent, easy to handle, non-toxic and non-allergic, providing moderate debridement, mechanical stability, and protection against microbial invasion and contamination are the general requirements for an ideal wound dressing .
4. **Tissue engineering**
   Previous transplant surgery will increase the chance of immunological rejection and surgical failure due to tissue antioxidant. As a possible matrix for skin regeneration, Rad et al. created PCL/Zein/GA nanocomposite scaffolds containing *Calendula officinalis* extract. *Calendula officinalis* contains several chemicals and has a wide range of benefits, including blood coagulation, anti-bacterial, anti-inflammatory, and free radical inhibition. Zein is a hydrophobic plant protein (the major and organ failure caused by injury, sickness, congenital handicap, age, or any other occurrence. However, as nanotechnology advances, tissue engineering scaffolds have emerged as a promising method for using drug carriers for effective target delivery and simulated extracellular matrix implantable biomaterials to repair or replace damaged tissues, thereby improving patients' health and quality of life.

CONCLUSIONS

Herbal medicine is utilized all over the world and contains a range of active substances (such as flavonoids, tannins, and terpenoids) that can be employed for antibacterial, anti-inflammatory, and cell proliferation purposes.

Because of their large surface area and porosity, as well as the features of mimicked ECM, nanofibers are employed to transport herbal medicine extracts and natural bioactive components in the development of a revolutionary herbal medicine delivery system. Electrospinning technique has been used in a variety of medicinal applications, including medication delivery, wound dressings, tissue engineering scaffolds, and biological food packaging.