SYNERGISTIC ROLE OF HERBAL BIOACTIVES AND MUCOADHESIVE POLYMERS IN THE MANAGEMENT OF SORE THROAT: A COMPREHENSIVE REVIEW OF LIQUORICE, GINGER, TULSI, SODIUM ALGINATE, AND CHITOSAN

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Abstract

Doctors frequently treat upper respiratory infections, which include sore throats. People need easy-to-use, effective methods of treatment. This review examines how more modern drug delivery techniques can be combined with traditional herbs to improve patient outcomes. Here are a few important plants. similar to ginger (Zingiber officinale), liquorice (Glycyrrhiza glabra), and tulsi (Ocimum sanctum). In addition to fighting bacteria and reducing inflammation, they also act as a natural coating for the throat. They also support the immune system, which appears to be crucial for respiratory issues. These, in my opinion, make sense for treating sore throats since they simultaneously address inflammation and infection. The idea of utilising mucoadhesive biopolymers to enhance the effectiveness of these herbs has emerged. For instance, chitosan and sodium alginate stick to the mucus in the throat. They stay there longer and release the herbal components gradually as a result. By erecting a kind of barrier, it shields the affected areas. Compared to conventional products like gargles or sprays that quickly wear off, this configuration is more long-lasting and improves the efficacy of the therapy. The transformation of this into well-known forms like pastes, gels, or lozenges is covered in the review. In vitro investigations on human oral fibroblast cells were conducted, and physicochemical characteristics were checked to standardise safety. It is comforting that it is non-toxic at the therapeutic dosages. All things considered, combining these herbal bioactives with polymer delivery technologies could be a viable substitute for conventional therapies for sore throats and related conditions. It is successful and promising, but more extensive clinical trials are required to validate it and integrate it into routine treatment truly.

1. Introduction

The management of upper respiratory tract infections, particularly the symptomatic relief of sore throat (pharyngitis), has seen a significant shift toward the integration of traditional herbal medicine with modern pharmaceutical delivery systems. Sore throat is a common clinical condition characterized by inflammation of the pharyngeal mucosa, often resulting from viral or bacterial infections, environmental irritants, or mechanical strain. While conventional treatments frequently rely on synthetic analgesics and antibiotics, there is a growing global recognition of herbal remedies due to their multifaceted therapeutic efficacy, favourable safety profiles, and alignment with holistic health approaches [1]. Herbal formulations are increasingly viewed as viable complementary or alternative options to conventional pharmaceuticals, especially in the context of rising antimicrobial resistance and the desire for treatments with fewer side effects. Among the diverse range of medicinal plants, Glycyrrhiza glabra (liquorice),Zingiber officinale (ginger), and Ocimum sanctum (tulsi) have emerged as primary candidates for respiratory care due to their potent anti-inflammatory, antimicrobial, and demulcent properties [1][2]

When these herbal bioactives are added to specific dose forms that guarantee extended contact with the afflicted mucosal tissues, their efficacy is greatly increased. In order to overcome the drawbacks of conventional liquid gargles or sprays, which frequently have brief residence durations in the oral cavity, modern pharmaceutical science has developed

mucoadhesive polymers such sodium alginate and chitosan. These biopolymers enable the prolonged release of active phytochemicals while facilitating the formation of a protective layer over the inflammatory mucosa, which has immediate calming benefits. Chitosan provides other advantages such wound healing and inherent antibacterial capability, whereas sodium alginate is valued for its film-forming properties and biocompatibility [4].

Researchers want to create patient-friendly delivery methods such as hard-boiled lozenges, gels, and pastes that maximise the natural constituents' therapeutic window by mixing these polymers with standardised herbal extracts [1] [5]. Additionally, in order to preserve structural integrity and palatability, the development of these formulations necessitates a thorough comprehension of the physicochemical interactions between the herbal powders and the excipients. In addition to serving as binders and sweeteners, excipients including liquid glucose, sucrose, and honey also help to soothe the throat overall [2] [5]. In vitro cytotoxicity tests are necessary to guarantee that the amounts of herbal extracts utilised in these formulations are not harmful to human oral cells, as safety is of the utmost importance. [3] The functional functions of sodium alginate and chitosan in mucosal drug administration, the pharmacological characteristics of liquorice, ginger, and tulsi, and the formulation techniques used to produce potent herbal lozenges and gels are all covered in this paper. The potential of synergistic herbal-polymer systems to offer a safe, natural, and efficient treatment for sore throat and associated oral mucosal disorders is highlighted in this paper by synthesising recent research findings.

An important development in ethnopharmacology is the shift from conventional decoctions to complex dose formulations. To treat disorders involving mucosal irritation and inflammation, for example, liquorice is used in hard herbal lozenges to allow for delayed dissolving in the mouth [1]. In a similar vein, adding tulsi and ginger to lozenges through heating and moulding processes offers a practical way to deliver antibacterial and anti-inflammatory substances straight to the infection site [2]. Incorporating these natural compounds into contemporary pharmaceutical frameworks offers a standardised method for therapeutic consistency and quality control in addition to validating conventional wisdom.
The creation of next-generation oral care products depends on an understanding of the synergy between herbal bioactive and mucoadhesive polymers, as the demand for natural healthcare products keeps growing.

2. Pharmacological Profiles in Respiratory Care

2.1. Glycyrrhiza glabra's Demulcent and Anti-Inflammatory Properties

Because of its broad pharmacological profile, Glycyrrhiza glabra, also referred to as liquorice, holds a significant place in both scientific and ethnopharmacological literature. Glycyrrhizin, a triterpenoid saponin that gives liquorice its distinctive sweetness and strong anti-inflammatory properties, is the main bioactive component of the plant. Liquice is a potent demulcent when used to treat respiratory conditions and sore throats. A demulcent is a chemical that coats a mucous membrane in a protective, calming layer, reducing inflammation and mild pain. Since the mucosal lining of the throat is frequently rough and sensitive, this characteristic is especially useful for treating pharyngeal irritation [1]. The suppression of pro-inflammatory cytokines and the inhibition of enzymes such as 11-beta-hydroxysteroid dehydrogenase, which raises local cortisol levels, are the mechanisms by which liquorice reduces inflammation. This double effect aids in lowering the redness and swelling brought on by sore throat infections.
It has been demonstrated that liquorice extract is safe for oral use in addition to its anti-inflammatory properties. Studies on the cytotoxicity of liquorice extract gels have shown that the material is not harmful to Human Oral Fibroblast (HOrF) cells at concentrations of 100 ug/mL over 24, 48, and 72 hours [3]. Because it guarantees that the plant's therapeutic benefits won't result in cellular harm to the oral cavity, this safety profile is essential for the creation of oral care products.

Liquorice's non-toxicity makes it a perfect addition to a variety of formulations meant for extended mucosal contact, such as gels, lozenges, and pastes. Additionally, liquorice has antioxidant and antibacterial qualities that enhance its calming effects, offering a multifaceted strategy for respiratory tract infections and oxidative stress [3].Using liquorice in hard herbal lozenges is a calculated decision to control irritation of the mucosa. Because these lozenges disintegrate gradually, the glycyrrhizin and other flavonoids can continually coat the throat.

The complete demulcent action requires this extended contact time because it creates a physical barrier that prevents additional irritation from coughing or swallowing. Furthermore, liquorice has been shown to have gastroprotective properties, which may help people whose heartburn or acid reflux is making their sore throat worse [1]. Liquice-based formulations provide a total therapeutic benefit by treating the throat's local inflammation as well as any possible underlying gastric causes. Thus, liquorice's incorporation into contemporary dosage forms fills the gap between conventional herbal knowledge and the safety and efficacy standards of modern pharmaceuticals.

2.2. Ocimum sanctum and Zingiber officinale's Antimicrobial and Calming Mechanisms

In traditional medical systems like Ayurveda, Zingiber officinale (ginger) and Ocimum sanctum (tulsi) are well known for their potent antibacterial and calming qualities. Bioactive substances found in ginger, such as shogaols and gingerols, have been thoroughly investigated for their capacity to stop the growth of several respiratory infections. These substances function by rupturing bacterial cell membranes and preventing the production of inflammatory mediators such as leukotrienes and prostaglandins. Ginger is used to cure sore throats because it has a warming effect that promotes local blood circulation, which speeds up the repair of irritated tissues [2.1]. The pungent quality of the substance also serves as an expectorant, assisting in the thinning and removal of mucus from the respiratory system. This helps to alleviate the congestion and cough that frequently accompany a sore throat.

The Zingiberaceae family includes ginger (Zingiber officinale), which is used as a spice in many different dishes and drinks all over the world. Ginger has long been used as a traditional medicine in Southeast Asia to cure fevers, coughs, sore throats, and digestive issues (1). Ginger's volatile and non-volatile chemical composition is what gives it its biological action. Ginger's volatile ingredients include sesquiterpenes and monoterpenoids, which are essential oils having a unique scent. The non-volatile ingredients, such as gingerol, shogaol, zingerone, and paradol, on the other hand, give ginger its strong, spicy flavour. The primary ingredient in fresh frontiersin.org Frontiers in Nutrition 01 Ayustaningwarno et al. 10.3389/fnut.2024.1364836 ginger is gingerol, which is subsequently transformed into shogaol, zingerone, and paradol in goods made from ginger (2).

Ocimum sanctum, often known as holy basil (tulsi), is frequently called the "Queen of Herbs" because of its many medicinal uses. It is abundant in essential oils, including as eugenol, which has strong analgesic, antibacterial, and anti-inflammatory properties. Tulsi is useful in treating bacterial and viral upper respiratory tract infections because it has been demonstrated to boost immunity. Tulsi has a calming effect on irritated mucous membranes and helps lower the microbial burden in the pharynx when administered in oral formulations [2]. When ginger and tulsi are combined in one form, like a lozenge, they have a strong synergistic impact. Tulasi offers broad-spectrum antibacterial defence and immunological support, whilst ginger concentrates on lowering inflammation and removing mucus. In a comfortable, patient-friendly manner, this combination is very useful for treating cough, minor respiratory infections, and throat irritation [2].

Additionally, the effectiveness of tulsi has been investigated in relation to more complicated oral disorders including oral submucous fibrosis (OSMF). Significant improvements in symptoms such as burning sensations and mucosal blanching were noted in investigations utilising herbal paste formulations containing tulsi, turmeric, and honey [5]. This implies that tulsi's calming and anti-inflammatory properties are strong enough to treat severe and long-lasting mucosal diseases. These same mechanisms function to quickly reduce discomfort and encourage the regeneration of healthy mucosal tissue in the case of a simple sore throat. Since honey is a natural demulcent and antibacterial agent, using it as a carrier in these formulations amplifies the calming effect [5] therefore, adding tulsi and ginger to respiratory care products offers a natural, scientifically supported substitute for artificial lozenges.

2.3 Immune system modulation by herbal bioactives

Both innate and adaptive immune responses are influenced by a number of endogenous and exogenous variables that contribute to immunostimulation and immunosuppression during the homeostatic state (10). In attempts to treat and prevent the causal agents, immune response modulation controls the immune response One of the most urgent problems in the treatment of many diseases nowadays is the use of immunomodulators. One of the most active areas of study for natural immunomodulators is the utilisation of bioactive chemicals produced from plants Because of their wide range of uses in preventing and treating disease through modifications to the immune response or oxidant-antioxidant state, natural immunomodulators are gaining popularity Antioxidants serve as a line of defence against the harmful effects of free radicals on the body's biological processes. There are two distinct pathways for antioxidants: endogenous and exogenous.The body can produce endogenous antioxidants through both enzymatic and non-enzymatic means in biological systems.

2.4 Herbal Combinations' Synergistic Therapeutic Effects on Pharyngeal Mucosa

In herbal therapy, the idea of synergy is essential, as the combination of several plants frequently has a therapeutic impact that is higher than the sum of their separate components. Liquorice, ginger, and tulsi work together to treat sore throats by targeting the pharyngeal mucosa in a number of ways. The main anti-inflammatory and demulcent base is

liquorice, which coats the throat and lessens redness. While tulsi offers broad-spectrum antibacterial and immune-modulatory assistance, ginger provides a thermogenic and expectorant element.

The complicated nature of pharyngeal infections, which frequently entail a combination of inflammation, microbial development, and physical discomfort, necessitates a multifaceted approach [1] [2]. Formulators can make a solution that not only reduces pain but also treats the underlying infection and encourages tissue healing by mixing these herbs. Other natural ingredients, such as honey and turmeric, are used to further strengthen the synergy between these plants. For instance, individuals with OSMF have demonstrated statistically significant improvements in oral mucosal health, including a decrease in palpable fibrous bands and an increase in mouth opening, after using a paste formulation of turmeric, tulsi, and honey [5]. The effectiveness of this herbal remedy demonstrates the strong anti-inflammatory and antioxidant synergy between tulsi and other bioactive ingredients, even though OSMF is a more serious ailment than a typical sore throat. These mixtures block inflammatory enzymes, neutralise free radicals, and produce a protective environment that promotes spontaneous healing when applied to the pharyngeal mucosa. Because honey functions as a humectant and natural preservative, keeping the mucosal surfaces moist, its use in these mixes is especially calculated [5]. Moreover, the formulation's physical characteristics also benefit from the synergistic impact. When ginger and tulsi extracts are mixed with liquorice powder in hard lozenges, the active ingredients are released gradually as the lozenge dissolves [1] [2].

For the pharyngeal mucosa to retain a therapeutic concentration of bioactive for a long time, this continuous release is essential. These synergistic herbal compositions stick to the throat and offer continuous treatment, in contrast to liquid gargles that are easily removed by saliva. A complete biochemical defence against infections and irritants is produced by the interplay of the many phytochemicals, such as the glycyrrhizin from liquorice, the gingerols from ginger, and the eugenol from tulsi. Compared to single-ingredient synthetic treatments that might only address one part of the illness, this holistic approach to throat care offers a considerable advantage.

3. Beneficial Roles in Mucosal Drug Administration

3.1. The Mucoadhesive and Film-Forming Properties of Sodium Alginate

Sodium alginate, a naturally occurring polysaccharide derived from brown algae, is crucial to modern mucosal drug delivery techniques due to its exceptional mucoadhesive and film-forming properties. The length of the dosage form's residence at the site of action is extended by the method by which a polymer sticks to the mucosal surface. Given that swallowing and the constant flow of saliva tend to swiftly clear medications, this is an essential precondition for treating a sore throat. Sodium alginate achieves mucoadhesion by forming hydrogen bonds and electrostatic interactions with the mucin glycoproteins present in the mucus layer.

By creating a physical bridge between the delivery mechanism and the pharyngeal mucosa, this guarantees that the herbal bioactives remain in contact with the inflammatory tissue for an extended amount of time. The ability of sodium alginate to form films is another essential property. When applied to a moist location, like the throat, sodium alginate can form a thin, flexible, and protective coating. This layer serves as a mechanical barrier that shields the sensitive nerve endings in the pharynx from external irritants such as food particles, smoke, and cold air. This immediate physical protection rapidly relieves the "scratchy" sensation associated with a sore throat.

Furthermore, the alginate matrix can be engineered to control the release rate of integrated herbal extracts. As the film hydrates and erodes, the active elements of liquorice, ginger, or tulsi are progressively liberated. By guaranteeing a steady therapeutic response and reducing the need for numerous doses, this enhances patient compliance. In addition to its useful properties, sodium alginate is valued for its safety and biocompatibility.

This non-toxic, non-irritating polymer is widely used in the food and pharmaceutical industries. When making herbal lozenges and gels, sodium alginate serves as a structural foundation that maintains the formulation's integrity while enhancing its therapeutic effectiveness. Its ability to gel in the presence of divalent cations, such as calcium, can be used to create more robust delivery methods, such as thickened gels or beads, that are particularly helpful for dental care [3].By adding sodium alginate to herbal compositions, researchers can transform simple plant extracts into intricate, highly effective mucosal delivery systems that maximise the relaxing and restorative qualities of the natural ingredients.

3.2. Chitosan Polymers' Antimicrobial and Wound Healing Properties

Chitosan, a linear polysaccharide derived from the chitin of crab shells, is a flexible biopolymer that shows significant potential for treating pharyngeal and oral problems. One of chitosan's most notable properties is its ability to hasten

wound healing. Chitosan has been shown in studies to effectively reduce ulcerative lesions and improve the healing process in a range of tissues [4]. In the event of a sore throat, when the mucosa may be ulcerated or severely inflamed, chitosan aids in the repair of the epithelial layer. Maintains the structural integrity of the pharyngeal lining during an infection by folding and offering a protective effect [4].

Chitosan's antibacterial properties make it even more useful for treating sore throats. Because of its cationic nature, chitosan has inherent antibacterial and antifungal properties. When the negatively charged elements of microbial cell membranes interact with the positively charged amino groups of chitosan, internal contents seep out and the cell dies. Because of this, chitosan is a great supplement to the antibacterial herbal extracts of tulsi and ginger. Together, the herbs and polymer offer a two-pronged defence against the bacteria that cause throat infections. Chitosan is generally well-tolerated by human tissues and does not contribute to antimicrobial resistance, in contrast to many synthetic antibiotics.

Additionally, studies have shown that chitosan is safe for use in medicinal formulations since it is non-cytotoxic and does not exhibit anti-proliferative characteristics against normal cell lines [4]. Its strength rests in its capacity to promote collagen synthesis and stabilise the wound site, both of which are essential processes in the healing process following mucosal damage, even though it might not exhibit strong anti-inflammatory activity in some models. Chitosan can operate as a mucoadhesive agent in the composition of herbal lozenges or pastes, holding the medicinal components in place while also actively promoting throat healing. Because of its capacity to combine with other polymers, including sodium alginate, it can be used to create sophisticated drug delivery systems with specialised release profiles and improved mechanical strength.

3.3. Interaction between Biopolymers and Herbal Extracts for Sustained Release

An important consideration in the creation of successful sustained-release formulations is the interplay between biopolymers such as sodium alginate and chitosan and herbal extracts. Herbal extracts or powders, such those from tulsi, ginger, and liquorice, become chemically or physically confined when they are distributed throughout a polymer matrix. How the active phytochemicals are released into the oral cavity depends on the type of trapping. For example, the swelling and subsequent erosion of the alginate matrix in a sodium alginate-based lozenge controls the release of glycyrrhizin from liquorice [1].The polymer chains in the lozenge loosen as saliva is absorbed, forming passageways that allow the herbal compounds to diffuse. The gradual nature of this procedure guarantees that the throat is continuously soaked in the medicinal compounds for at least 15 to 30 minutes.

Because of its pH-sensitive characteristics, chitosan can also be employed to control the release of herbal active ingredients. Chitosan-based systems can be made to release varying amounts of the herbal extract in response to variations in the pH of the oral cavity, which can occur during an infection or after eating. Moreover, polyelectrolyte complexes can be created when sodium alginate and chitosan are combined. Compared to either polymer alone, these complexes frequently exhibit superior mucoadhesive qualities and are more stable. Such a combination may offer a better film-forming action in a formulation for sore throats, keeping the antibacterial properties of ginger and tulsi against the pharyngeal wall and inhibiting their rapid swallowing [2] [4].
The leap from basic traditional remedies to sophisticated pharmaceutical products is made possible by the synergy between the biopolymers and the herbal bioactive.

This interaction is further influenced by the use of excipients such as liquid glucose and honey. For instance, honey can serve as a natural plasticiser for polymer films, increasing their flexibility and patient comfort (51). As shown in formulations for herbal pastes, it also offers a secondary matrix that can keep herbal powders in suspension.

The viscosity and rate of dissolution of the finished product are affected by the presence of these sugars and natural binders. Formulators can create a release profile that offers a prolonged therapeutic impact in addition to an initial "burst" of relief by carefully adjusting the ratios of sodium alginate, chitosan, and herbal extracts. In order to maximise the effectiveness of herbal medicines in treating acute illnesses like sore throat, where both immediate and sustained action are required, this advanced control over drug administration is crucial.

4. Role of Excipients in Enhancing Palatability and Structural Integrity

Excipients are crucial ingredients in herbal preparations, fulfilling purposes beyond simple "fillers." Excipients like sucrose and liquid glucose are essential for giving herbal lozenges the required structural integrity and "mouth feel" during manufacture." By acting as a plasticiser, liquid glucose keeps the sugar from crystallising and keeps the lozenge translucent and smooth. It also adds to the lozenge's hardness, which is essential for its slow-dissolving properties [2].

If these sugars are not balanced properly, the lozenge may be excessively soft or brittle, which would result in an uneven release of the herbal active ingredients. Additionally, these excipients improve patient tolerability by adding the sweetness required to cover up the bitter or strong flavours of herbs like ginger and liquorice.

Another versatile excipient that is commonly used in herbal oral care is honey. Honey acts as the main vehicle in paste formulations, offering a thick viscosity and a natural sweetness that promote mucosal adherence. In addition to its physical characteristics, honey has inherent antibacterial and calming capabilities that enhance the herbal components [5]. It works well with tulsi and turmeric because it soothes the throat and offers a protective layer. The "natural" appeal of herbal products, which plays a big role in customer choice, is also consistent with the usage of honey. Honey can even serve as a natural preservative in some recipes, negating the need for artificial additions.

To achieve the required viscosity and mucoadhesive qualities, gel formulations may employ additional excipients, such as carbomers or cellulose derivatives. A carbomer-based foundation, for instance, can be used to make a liquorice extract gel, guaranteeing the gel's stability and ease of application [3]. When the herbal extract comes into touch with the oral mucosa, these polymers aid in controlling its release and helping to suspend it. The stability of the herbal bioactives must be taken into account while choosing excipients. The excipients and manufacturing technique must be chosen to minimise deterioration because some phytochemicals are sensitive to heat or pH fluctuations.Formulators can produce herbal medicines that are stable over time, comfortable to use, and therapeutically efficacious by optimising the excipient profile.

4.1. Standardized Parameters for Quality Control and In Vitro Cytotoxicity Assessment

Standardised quality control requirements must be closely adhered to in order to guarantee the safety and effectiveness of herbal lozenges and gels. These factors include disintegration time, hardness, friability, and weight fluctuation for lozenges. Testing for weight fluctuation guarantees that the herbal-sugar matrix is present in a constant quantity in each lozenge. To make sure the lozenge can survive handling and transportation while still dissolving in the mouth at the proper rate, its hardness is assessed. Friability testing evaluates the lozenge's ability to withstand breakage and abrasion. Since lozenges are meant to dissolve gradually rather than disintegrate rapidly, disintegration time is very crucial (2). A baseline for the formulation's structural quality is provided by these physical tests.

For patient-friendly goods, organoleptic examination is essential in addition to physical testing. This entails evaluating the lozenges or pastes' colour, aroma, and acceptability of taste. Compliance requires the use of sweeteners and flavor-masking chemicals to achieve an acceptable taste because herbal substances can have strong and occasionally disagreeable flavours (2). For example, ginger's pungency and liquorice's sweetness can be combined to provide a flavour profile that is both palatable and therapeutic. During the development stage, standardised taste panels are frequently utilised to assess these attributes.

Possibly the most important component of quality control is safety assessment. To make sure the herbal extracts and the finished mixture are safe for human usage, in vitro cytotoxicity tests are carried out. Testing the formulation against Human Oral Fibroblast (HOrF) cells is a popular technique. For instance, research on liquorice extract gel has demonstrated that over a 72-hour period, a concentration of 100 ug/mL is not harmful to these cells [3]. In a similar vein, chitosan's anti-proliferative and cytotoxic properties have been examined, demonstrating its suitability for mucosal applications (4).

The scientific proof required to support the therapeutic use of herbal products is provided by these evaluations. Additionally, objective and subjective symptoms—such as burning and mouth opening—are documented and statistically evaluated in patient-centered trials, like those for OSMF, to verify the formulation's effectiveness [5]. Herbal treatments are guaranteed to meet the same quality and safety criteria as traditional pharmaceuticals thanks to this thorough screening process.

5. Conclusion

An important development in the treatment of sore throat and oral mucosal problems is the combination of mucoadhesive polymers such sodium alginate and chitosan with herbal bioactives like liquorice, ginger, and tulsi. From the soothing and antimicrobial effects of Zingiber officinale and Ocimum sanctum to the demulcent and anti-inflammatory effects of Glycyrrhiza glabra, this review has emphasised how these plants' distinct pharmacological qualities can be used to effectively relieve symptoms and aid in the healing process [11][2][3]. By offering a protective physical barrier and guaranteeing the continuous release of active substances at the site of inflammation, the use of biopolymers amplifies these benefits even more [4].

Convenient, standardised, and patient-friendly dose forms are created from these natural treatments using advanced formulation techniques, such as the creation of herbal pastes and hard-boiled lozenges [21[5]. These synergistic combinations provide a multi-targeted approach to respiratory therapy, according to the research presented. Ginger and tulsi help to clear the throat of germs and lessen swelling, while liquorice coats and shields the throat. In addition to improving the delivery system's mechanical qualities, the combination of sodium alginate and chitosan offers inherent therapeutic advantages such improved wound healing and more antibacterial support [1][4 Additionally, in vitro cytotoxicity tests have confirmed the safety of these formulations by showing that the quantities of herbal extracts utilised are non-toxic to human oral cells [3]

The ability of these natural compounds to heal even severe mucosal disorders is further demonstrated by the effectiveness of herbal pastes in treating complicated conditions such oral submucous fibrosis [5]. Nevertheless, much more needs to be done to fully realise the promise of these herbal-polymer systems, even with the encouraging results. Future studies ought to concentrate on a few important topics. First, more thorough clinical studies are required to compare these formulations directly to conventional synthetic medicines and validate their effectiveness in a range of patient populations. Large-scale, double-blind, placebo-controlled trials are the gold standard, even though in vitro and small-scale human research are promising.

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