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Some Important Applications of Using Sodium Alginate: Review

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Abstract

Alginate is a biological substance with many uses in engineering and biological sciences. Its exceptional properties, namely its excellent biocompatibility and simple gelation, make it widely use. Numerous cross-linking methods, for example, can be used to create alginate hydrogels. Their structural similarity to extracellular matrices present in living tissues makes them highly useful for wound healing and the delivery of chemotherapeutic, tiny proteins, and transplanted cells. Alginate is also frequently employed in a variety of technologies, such as tissue engineering cell transplantation and different biomolecule immobilization techniques. This study will discuss the main features of alginates and hydrogels, their biological functions, and new pathways to research these polymers in the future

Keywords: Immobilization, Alginate, Enzymatic efficiency.

Introduction

Alginate has revolutionized the use of proteins and enzymes in food, clothes, medicines, medical advancements, and the environment. Alginate is a biopolymer that possesses distinct physical and chemical characteristics, which render it a perfect substrate for protein attachment. It is commonly recognized that immobilizing enzymes on alginate results in changed catalytic activities and increased operational stability with few to no side effects. Alginate is widely

utilized as an encapsulating material for dietary proteins to improve their gastrointestinal absorption and to deliver various proteins and peptides for medicinal purposes due to its GRAS (Generally Recognized as Safe) classification. Alginate is the preferred support for the purification of enzymes and proteins using straightforward chromatographic separations and affinity precipitation due to its unique interactions with proteins as a function of ionic strength, pH, and metallic ions. However, the usage of an additional pure form of alginate is required for its biomedical in vivo application, particularly in tissue engineering. This paper investigates the ability of aligned and sodium alginate to immobilize one of the hydrolyzing enzymes and highlights certain main application areas where Alginate is utilized extensively.

Chemical structure of sodium Alginate

Alginate is the preferred support for the purification of enzymes and proteins using straightfor ward chromatographic separations and affinity precipitation due to its unique interactions with proteins as a function of ionic strength, pH, and metallic ions [1]. However, the usage of an ad ditional pure form of alginate is required for its biomedical in vivo application, particularly in t issue engineering. This paper looks at the ability of aligned and sodium alginate to immobilize one of the hydrolyzing enzymes and highlights certain main application areas where alginate i s utilized extensively. The stereo chemical properties of manuronic and glucuronic acid mono mers can vary based on the M/G mix and chain sequencing, potentially affecting the flexibility of alginate chains. Moreover, X-ray patterns revealed that the amorphous structure of alginate and AA salts exhibited a degree of increased structural organization [2],[3]. Two peaks of diff raction at 16 and 21◦, suggesting a specific order, are due to the presence of homopolymeric bl ocks (MM or GG) in the molecular chain of AA (4. Alginates are highly valued for their capac ity to form gels either through acid precipitation or by selectively binding multivalent cations. Temperature does not affect the sol/gel transition of alginates, in contrast to other polysacchari des such as gelatin and agar (5). Meanwhile, calcium-alginated gels find are widely used in me dical such as control-release drug delivery systems, enzyme immobilization, and wound dressi ngs (6). This review does not address this alginate salt since it is not frequently utilized as an e xcipient in the direct compression method of tablet manufacturing. The correlation between th e gel's structure and mechanics and the alginates' chains is influenced by factors such as the ty

pe of ion, sequencing, and composition of the alginate chain, which ultimately impacts its stiff ness. Therefore, the total amount of α-L-glucuronic acids and, in particular, the length of G-bl ocks (7) are crucial factors in determining if algae can create gels. This method led to the creat ion of soft, elastic gels due to MM blocks, with flexibility provided by MG blocks, while a hig h proportion of GG blocks led to a hard and brittle gel (8). These findings have been authentic ated through the application of bond-angle correlation function calculus to the stiffness of NaA blocks (9). The study revealed the complexity in characterizing the adaptable nature of alginat e chains, which is influenced by factors such as the monomer series, alginate as concentration, counterion kind, strength of ion, and sample polydispersity. Illustrating the complexity, variou s interchain association mechanisms such as entanglement, zipper mechanism, and lateral asso ciation can be observed by adjusting the glucuronic content of the Na chain. Scientists have alt ered alginates to create more precise structures and unique compositions with narrower distrib utions than those naturally occurring. This was achieved by using Mannuronan C5-epimerases (AlgE4) to investigate the molecular dynamics affecting the physical properties of alginates in solution and gel form. To learn more about the alginate molecule's main features, these more undersized variable sequences should help in discovering connections between structure and p roperties without having to rely on statistical assumptions (8). The greater acid solubility of alt ernate sequences formed by AlgE4 in AA gel formation was described, for instance, by the en hanced conformational entropy of the undersized extended epimerized chains and a deficiency of intermolecular cross-linking between them. Because alginates' structure affects their gellin g capacity and medication administration behavior in addition to their mechanical qualities in powder form, thorough assessment of these materials is required(10,11). Required to complet ely comprehend the connection between the structure and functionality of algae.

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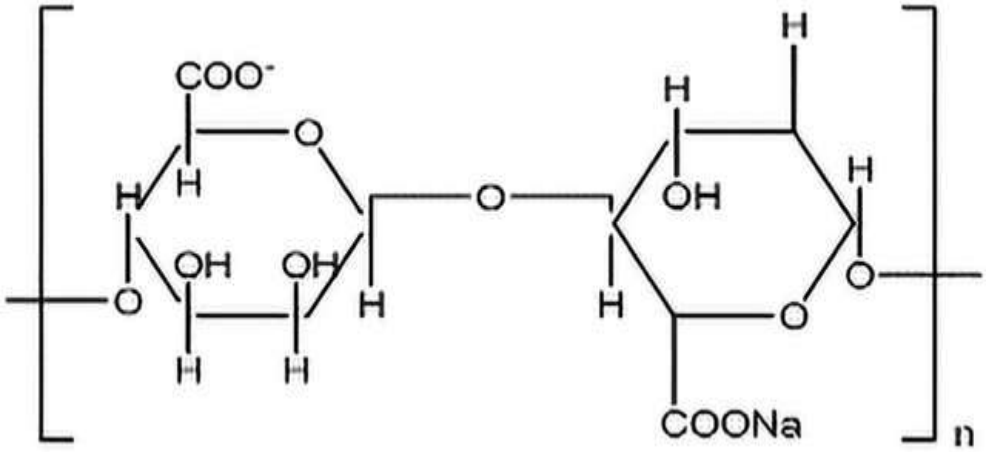

Figure 1: Sodium alginate Chemical structure

Immobilization Enzyme Support

Enzyme immobilization has generated attention in a variety of industrial applications as well as fundamental academic research [12]. The principle of enzyme immobilization is to encase the enzyme in a semi-permeable subsidy material that keeps the enzyme from escaping while letting substrates, products, and co-factors flow through [13]. The immobilizing matrix must be inert andenzyme-friendly, although the exact specifications could differ depending on the enzyme type and application. It is also important that the immobilization technique is mild enough to avoid denaturing the enzyme. When utilizing an immobilized enzyme in vivo, the support material should also avoid immune recognition. This is especially important if the enzyme does not originate from a human [14][15]. When it comes to immobilization and microencapsulation procedures, alginate is the polymer that is utilized the most frequently. Elements of a-l-glucuronic acid and b-d-mannuronic acid alternate in the chains that make up alginate, a seaweed extract [16, 17]. The process of creating alginate supports typically involves crosslinking the carboxyl group of a-l-glucuronic acid using a cationic cross linker solution, such as poly(l-lysine), calcium chloride, or barium chloride [18, 19]. Nevertheless, alginate matrices crosslinked with Ca2+ ions may lose stability in physiological environments or common buffer mixes containing high concentrations of phosphate and citrate ions, leading to the extraction of Ca 2+ from the alginate and causing the system to liquefy (see fig .2). Enzyme immobilization on different surfaces plays a vital role in enhancing enzyme stability and efficiency while reducing enzyme process expenses [20]. Immobilizing a model xylanase

(PersiXyn9) obtained from metagenomics samples was achieved using GO-containing reinforced nanocomposites. The hydrogels' polysaccharide backbone allows for control over the samples' microstructure and net charge. In addition to significant morphological and architectural alterations, the addition of GO Nano-filler also reduced their capacity to absorb water. Hydrogel Z-potential values were most affected by the biopolymer's kind and charge. However, the GO nano-filler's oxygenation activities resulted in the polymer matrixes becoming negatively charged. An examination contrasting the application of many hydrogels as a vehicle for enzyme immobilization revealed that the bio-polymer [21].

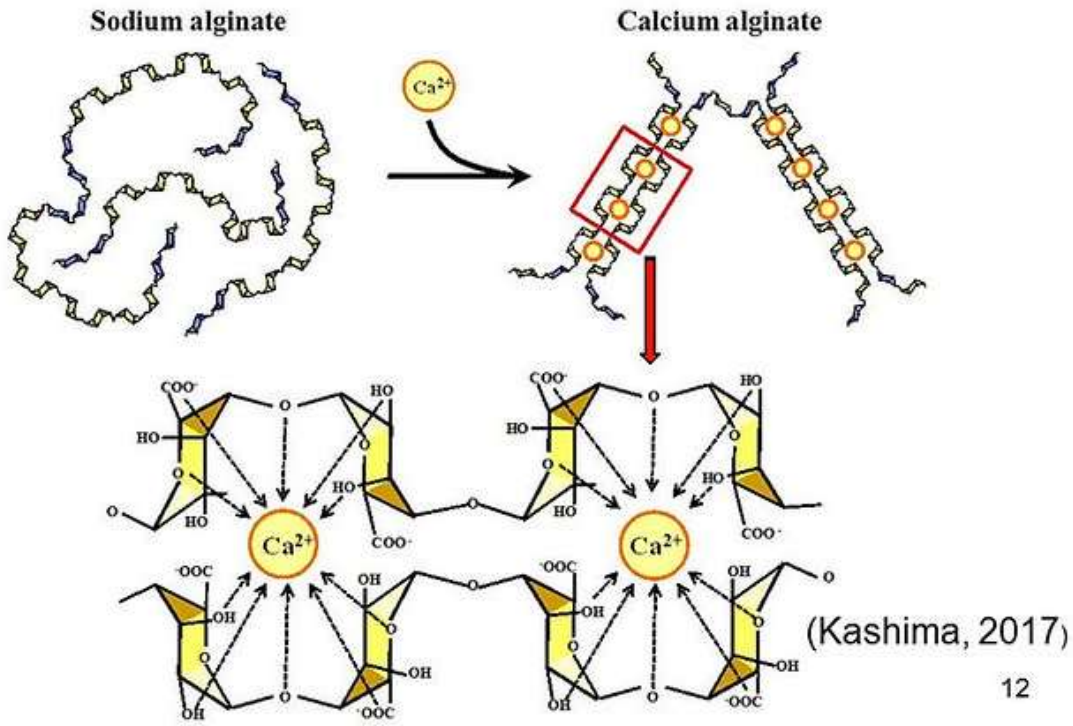

Figure 2: alginate interact with the positive charge calcium ion.

Cancer Diagnosis

Most countries are seeing an increase in the global cancer burden. Therefore, tremendous efforts are being made in oncological research to solve these issues. Encapsulation represents a viable approach in this regard [22]. Beads are the end product of encapsulation, the procedure

of encasing liquid, solid, or gaseous molecules in a serial shell. The diameter of the microbeads varies from 1 to 1000 μm, while that of Nano beads is measured between 10 and 1000 nm. If a bead is made up of the essence of a restricted compound encircled by a coating or shell, it is referred to as a "shell/core capsule" or as a "sphere" if it is spherical and contains scattered active chemicals [23]. Therapeutic substances that are encapsulated can be delivered under control thanks to encapsulation [24]. The matrix composition has a significant impact on the release profile. As a result, it decides how well the delivery system works. For a coating material to be utilized in biomedical applications, it must meet some basic standards, including appropriate physical-chemical properties and biocompatibility. Typically, encapsulation uses both natural and synthetic polymers [25]. Poly lactic acid (PLA) [26], poly glycolic acid (PGA) [27], poly(D,L-lactide–co–glycolide) (PLGA) [28], polyethylene glycol (PEG) [29], poly(vinyl alcohol) (PVA) [30], poly caprolactone (PCL) [31], poly (beta-amino esters) (PbAE) [32], and ethylene-vinyl acetate (EVA) [33] are a few examples of synthetic polymers that have been used as delivery systems. Alginate [34], pectin [35], chitosan [36], cyclo-dextrins [37], dextran [38], agarose [39], hyaluronic acid [40], carrag-geenan [41], fucoidan [42], starch [43], poly hydroxybutyrate (PHB) [44] and poly (3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) [45] are examples of natural polymers used as coating materials. Additionally, proteins like keratin [46], gelatin [47], albumin [48], collagen [49], and gliadin are examples of natural polymers. Because of polysaccharides are abundant in nature and come from bases of regenerative base, they are particularly valuable for biomedical applications because of their great range of compositions and configurations [50]. They are biodegradable, extremely soluble in water, stable, and non-toxic [51]. Among other reasons, this evaluation concentrates on alginate because of these qualities. Biomaterial depiction highlights the combination of two natural polymers, sodium alginate, and chitosan. As well as the incorporation of nanoparticles that can provide CT and MRI imaging contrasts to guide radiation and enhance therapeutic results fig (3).

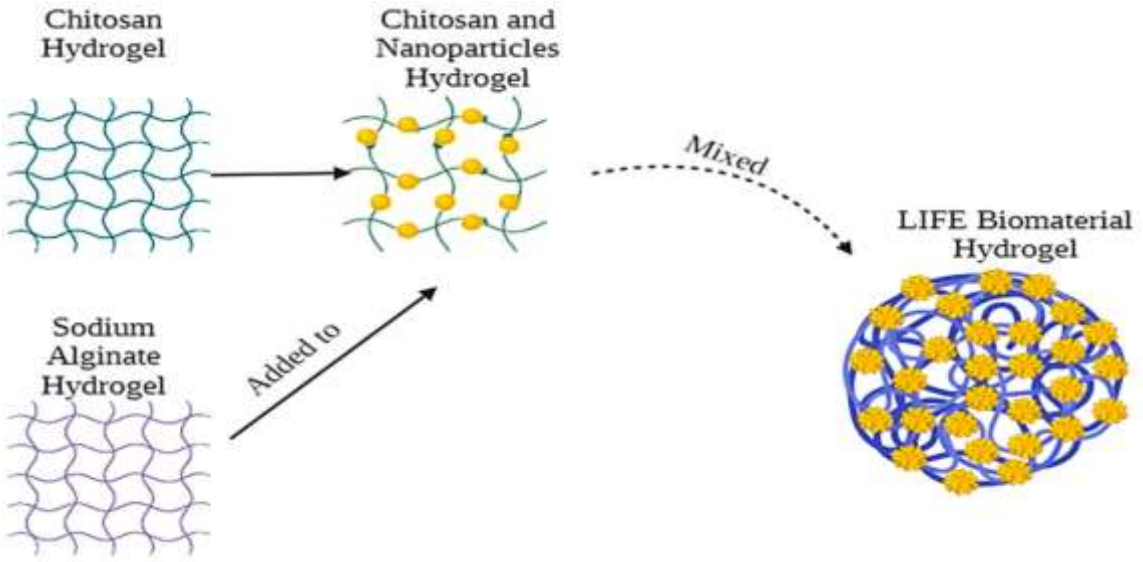

Figure 3: biomaterial portrayal emphasizes the combination of two natural polymers, sodium alginate and chitosan, as well as the addition of nanoparticles that can offer CT and MRI imaging contrasts

An Essential Part of Bio-Based Polymer Composites: Sodium Alginate

The necessity to replace traditional materials based on oil led to the invention of bio-based polymer materials. They are designed to be indifferent to the biological systems they house. Alginates hold a particular place among the majority of hydrocolloids employed because they are among the most well-liked and researched polysaccharides [52]. The US Food and Drug Administration has classified alginates as GRAS (generally recognized as safe) pharmaceuticals [53], while the European Food Safety Authority has authorized the use of alginate and related salts at quantum statis doses [54].

Water treatment

One of the most significant environmental problems facing the world today is water contamination, which dye molecules, heavy metal ions, oil spills, etc can bring on. The introduction of very toxic and none bio degradable substances into the water by these pollutants has led to long term environmental impact (55,56) There are two ways that SA composites are used to treat wastewater: adsorption (using sodium alginate ,fig .4) and filtering, which remove contaminants from the water. Both adsorption and filtration materials have remarkable

qualities, including the ability to remove impurities selectively and at a millimeter scale. They are also safe to use and recycle, making them viable options for real-world applications

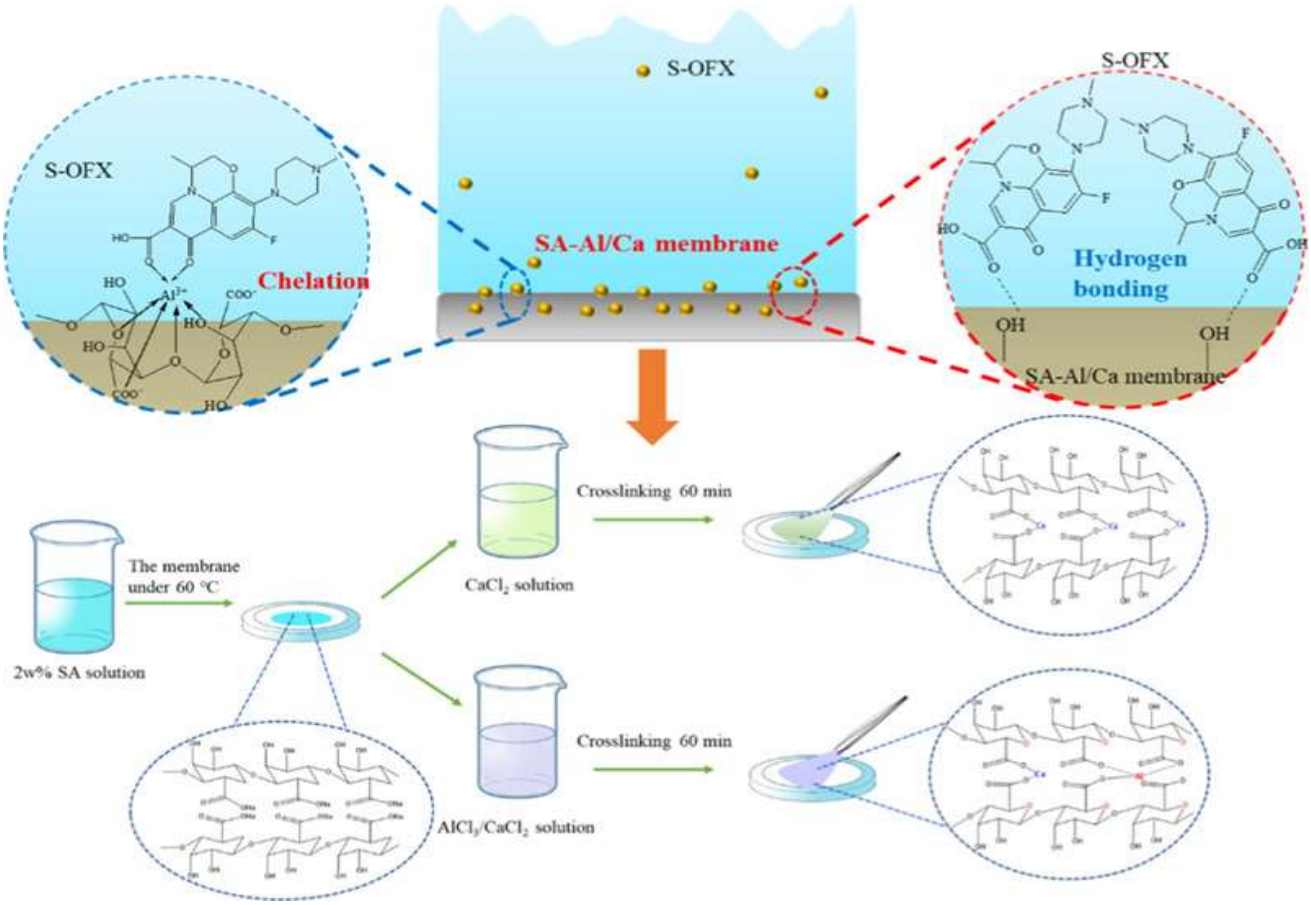

Figure 4: usage sodium alginate in water treatment

Carbonization

Sodium alginate, which is nontoxic and renewable, is a great alternative to conventional carbonaceous materials obtained from petroleum for the manufacture of carbon sources. A critical step in creating porous carbon materials for energy storage (57) and adsorption is carbonization of SA hydrogels and aerogels in an inert environment (N2 or Ar). (58) To create carbon aerogels based on SA with a large surface area and plenty of micro pores, physical and chemical activation techniques are typically employed. Wang et al. (59), for instance, created hierarchical porous carbon aerogel materials for supercapacitors that were generated from SA aerogels (60). Alginate aerogels were carbonized in an argon environment to produce porous

carbon aerogels, or PCAs. The resulting hierarchical macro-meso micro porous carbon aerogels (APCAs) were produced by activating the KOH solution in a nitrogen flow. The carbon materials that were produced have a large number of micro- and macro pores.

Antioxidant Activities of Alginate

Different chemical reactions, as well as exposure to ultraviolet light and ionizing radiation, can result in the production of reactive oxygen species (ROS). Some examples of ROS include hydrogen peroxide (H2O2), hydroxyl radical (•OH), and superoxide anion (O2-). Many cellular metabolic processes, such as respiration, lead to the generation of reactive oxygen species (ROS). Superoxide dismutase and other antioxidant enzymes regulate the levels of reactive oxygen species (ROS) in living organisms .When there is an excessive formation of reactive oxygen species (ROS), lipids fall into the category of being vulnerable to oxidative stress (61).

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