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A Comprehensive Review on Alginates

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Abstract--- ***Polysaccharides and its derivates from renewable sources had drawn attention as attractive compounds that can be used as substitutes over nonrenewable synthetic materials. Alginates are naturally occurring polysaccharides with unique physiochemical properties that have applications in biomedical and pharmaceutical fields. The most useful and unique property of alginates is their ability to react with polyvalent metal cations, specifically calcium ions, to produce strong gels or insoluble polymers. Polymer blends combined of alginates with other biopolymers are expected to bring changes in the polymer industry due to their unique biological and pharmacological activities. These blends find applications in medical and pharmaceutical field, food technology, as imprint matrices, and agriculture field. This paper focuses in an in-depth review on alginates. The structural chemistry, their various properties and applications are studied. The blends and composites that have been prepared with alginates and their properties are also highlighted.***

Keywords--- ***Alginates, Biopolymers, Medical Uses, Drug Delivery.***

I. INTRODUCTION

Immense progress has been made in the field of biomaterials in recent years owing to the concerned ecological problems. Various kinds of biomaterials that have the potential to substitute the synthetic materials are being studied vastly ranging from natural filler particles to polymers that can be extracted from natural sources. Due to the unique physiochemical properties and adaptable biological activities, alginic acid, natural multifunctional polymers, pioneer among the biomaterials that are being researched for different fields of applications like biomedical and pharmaceutical applications[1]. Alginic acid, also called, algin or alginates are naturally occurring anionic polysaccharides that can be derived from cell walls of brown algae including, *Macrocystispyrifera, Laminariahyperborea, Ascophyllumnodosum* and various bacterial strains [2, 3]. The properties like biodegradability, bio compatibility, non-toxic behaviour and low cost, would render alginates, an excellent candidate in biological applications. Toxicological data showed that alginates are safe when used in food. Sodium alginate is one of the most widely investigated ones among the group of alginates in the pharmaceutical and biomedical field. Due to its property of forming highly viscous solutions, alginic acid is widely used as an added product to food [5]. Alginates can act as is a potential biopolymer film or coating component because of its unique colloidal properties, which include thickening, stabilizing, suspending, film forming, gel producing, and emulsion stabilizing feature[23]. The alginates have ability to react with polyvalent metal cations, specifically calcium ions, to produce strong gels or insoluble polymers that can be used in the food processing industry for producing restructured foods such as meat products, onion rings, pimento olive fillings, crabsticks, and cocktail berries [33].

II. CHEMICAL STRUCTURE OF ALGINATES

Alginates are linear biopolymers consisting of 1,4-linked β-D-mannuronic acid (M) and 1,4 α-L guluronic acid (G) residues arranged in homogenous (poly-G, poly-M) or heterogeneous (MG) block-like patterns [6,7,8] as shown in fig.1. Because of the particular shapes of the monomers and their modes of linkage in the polymer, the geometries of the G-block regions, M-block regions, and alternating regions are substantially different [9]. The composition and extent of the sequences, and the molecular weight determine the physical properties of the alginates. The content of uronic acids varies with species and tissues types, and partial acid hydrolysis of alginic acids allows the preparation of fractions enriched in hetero and homopolymeric blocks[10, 11]. The gel network induced by cooperating Ca^{2+} into poly G chain segment, form stable junctions, that consists of diamers, and are usually referred to as egg-box model[21].Alginic acid is the only polysaccharide, which naturally contains carboxyl groups in each constituent residue, and possesses various abilities for functional materials [23]. The extraction process of alginates from sea weeds is a multi stage process, starting with the treatment of dried raw material using a diluted mineral acid, followed by purification and conversion into water soluble sodium salt in the presence of calcium carbonate, and further transforming back into acid, or its expected salt. Alginates, salts of alginic acid, are widely used in various industrial sectors and can beprepared through the exchange of sodium ions from guluronic acid by divalent cations, suchascalcium,andthroughtheformationofelectrostaticbinding between guluronic residues.

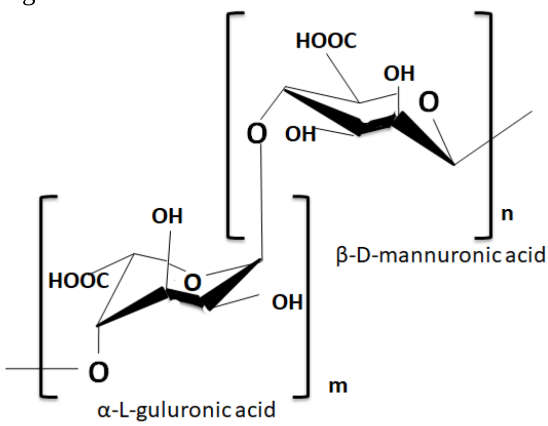

Figure 1: Molecular structure of alginic acid

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III. PROPERTIES AND APPLICATIONS OF ALGINATES

Ordinary alginate samples are chemically heterogeneous [4]. Alginic acid is insoluble in water and organic solvents, but its monovalent salts and esters are water soluble. Because of their unique property of sol/gel transition, these alginates can be easily formed into semisolid or solid structures [1]. The gelling properties are related with the structure and the proportions of M-, G-, and MG blocks [12]. The increasing repeating units of G- blocks results in more stable alginate gels [13] whereas with more M- blocks results in more soft and elastic gels. Alginate forms a stable hydrogel in the presence of low concentrations of divalent cations, such as Ca^{2+}, Sr^{2+}, and Ba^{2+}, through ionic interactions with the carboxylic functional groups on G units in the alginate molecular chains [14].It is the biological properties that make alginates to pioneer among biopolymers, which include biocompatibility, bio adhesiveness, hydrophilicity and non toxic behaviour. Though edible films prepared from hydrocolloids like alginate form strong films, they exhibit poor water resistance because of their hydrophilic nature [23]. Table.1 shows the physiochemical properties of alginates accompanied with relevant applications. Apart from these applications, alginate microparticulate systems are being studied for treatment of diseases like cancer, diabetes or Parkinson's diseases [1]. Alginate, being an anionic polymer with carboxyl end groups, is a good mucoadhesive agent and an attractive material for the fabrication of composite coatings by electrodeposition [19]. The pore size of alginate gel microbeads has been shown to be between 5 and 200 nm and coated beads and microspheres are found to be better oral delivery vehicles. Calcium ions cross-linked alginate films were developed by Liling etal., and the films showed enhanced properties [25]. Cross-linked alginate has more capacity to retain the entrapped drugs and mixing of alginate with other polymers such as neutral gums, pectin, chitosan, and eudragit have been found to solve the problem of drug leaching[9]. Yoshioka etal.[15] had prepared alginic acid layers on stainless steel substrates for biomedical applications. Alginic acid-coated chitosan nanoparticles have been developed as an oral delivery carrier for a legumain DNA vaccine [16]. Calcium alginate [18] layersformedonthe electrodepositedtricalcium phosphate coatings can promote bone regeneration. Algae oligosaccharides generated with the degradation of alginates get consumed by micro organisms and plants[24].

Table 1: Properties of alginates suitable for various applications

Property	Applications
In situ gelation, gelling property	Tissue engineering, drug delivery system, taste masking agents, immobilization of cells, encapsulation, biocatalysis, imprinted matrices
Hydrophilicity	Drug delivery system, encapsulation of drugs
Biocompatibility	Food industry(emulsifier, thickener), wound dressing, cell grafting, regeneration of skin, agricultural mulching films
Bioadhesiveness	Medical applications, surface modifications, biological reagents, bio opto-electronics
pH sensitivity	Drug delivery system

IV. ALGINATE BASED BLENDS AND COMPOSITES

Alginates have been blended with other polymers or materials to form blends/composites. Chitosan is a co polymer of D-glucosamine and N-acetyl glucosamine, which have applications in food and pharmaceutical fields. Huang etal. [17] had prepared composite membranes consisting of an active alginate layer and supporting chitosan layer on top of the base porousn-blended polyvinylidene fluoride (PVDF) membrane. They showed permselectivity for the dehydration of ethanol and isopropanol mixtures. A study on co-deposition of alginic acid, hydroxyapatite (HA), TiO_2 and chitosan, resulted in the fabrication of novel nanocomposite films that showed corrosion protection of shape memory alloy substrates in Ringer's physiological solutions [19].Bionanocomposites with methyl cellulose/sodium alginate/montmorillonite showed wound healing properties [20]. Proton conducting anhydrous polymer electrolytes consistingalginic acid/1, 2, 4- Triazole, with film forming properties that could be made use in electrochemical devices and sensors were developed by Gunday etal. [22]. Silica/poly-L-lysine/alginate nanocomposites have been synthesized and characterized to be made useful in drug delivery systems [27]. Aerogels formed of alginic acid and graphene oxide prepared via sol-gel method were reported to act as adsorbents, because of the porous nature [28]. Another study reports the effective blending of alginic acid/polyethylenimine, which can be used to deliver nucleic acids to mammalian cells [29]. Polymer composites of alginic acid and benzimidazole, are reported to be regarded as excellent candidates for membranes in fuel cells [30]. Superabsorbent hydrogels consisting of alginate, 2-acrylamido-2-methyl-1-propanesulfonic acid (AMPS) and Na+ montmorillonite (MMT) have been developed by Yadav etal.[31]. Bayer etal.[32] had studied alginate films as imprinted matrices.

V. CONCLUSION

Alginate is a natural material, harvested from brown algae, that finds widespread use as a food additive, in pharmaceutical formulations, in wound healing and in tissue engineering. 1,4-linked β-D-mannuronic acid (M) and 1,4 α-L guluronic acid (G) constitutes the chemical structure of alginic acid. Alginates and its blends/composites are being researched widely, and find applications in different fields with enhanced properties. Undoubtdly, these composites and blend of alginates will nourish the medical and pharmaceutical industries both economically and ecologically.

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