Algerian Journal of Natural Products 4:3 **(2016)** 348-357

OPEN ACCESS

Online ISSN: 2353-0391

Algerian Journal of Natural Products

www.univ-bejaia.dz/ajnp

Type of the Paper (Review)

NATURAL POLYMERS: CELLULOSE, CHITIN, CHITOSAN, GELATIN, STARCH, CARRAGEENAN, XYLAN AND DEXTRAN

F. Z. BENABID[1]* and F. ZOUAI[2]

[1]LMPMP, Faculté de Technologie, Université Ferhat ABBAS Sétif-1, Algérie
[2] Unité de Recherche Matériaux Emergents,
Université Sétif-1, Sétif 19000, Algérie

Author to whom correspondence should be addressed; E-Mail: fzbenabid@univ-setif.dz

Received: 31/07/2016 /Accepted:09/12/2016 DOI: https://doi.org/10.5281/zenodo.199036

Abstract: Biopolymers have been investigated for drug fields. They are widely being studied because of their non-toxic and biocompatible in nature. Biopolymers are used in industries as diverse as paper, plastics, food, textiles, pharmaceuticals, and cosmetics.This review covers different natural polymers, recent techniques applied in their processing and characterization. Advanced applications of natural polymers, including chitin, chitosan, alginate, etc., are discussed.

Keywords: Natural polymers, applications, chemical structure, properties

I. Introduction

Natural polymers have received attention as economical, readily available and non-toxic materials. They are capable of chemical modifications, potentially biodegradable and with few exceptions, also biocompatible [1].

Biopolymers are available in large quantities from renewable sources, while synthetic polymers are produced from non-renewable resources.

The polysaccharides represent one of the most abundant industrial raw materials and have been the subject of intensive research due to their sustainability, biodegradability and bio-safety [2]. We review here a selection of the most important natural polymers that have been studied and exploited in several fields.

II.Natural Polymers

Biopolymers are produced in the growth cycles of cells of living organisms. They offer a variety of applications that have the advantages of conventional plastic and don't burden the environment. The advantages of these materials are that large quantities are constantly available at a reasonable price.

II.1.CELLULOSE

Cellulose is an organic polysaccharide located within the fiber walls of plants. This natural polymer is the most important and fascinating biopolymer.

Cellulose is insoluble in water and most common solvents, used in a wide range of applications including composites, netting, upholstery, coatings, packing, paper, etc [3]. Many parallel cellulose molecules form crystalline microfibrils that are mechanically strong and highly resistant to enzymatic attack [4]. These are aligned with each other to provide structure to the cell wall [5, 6].

Chemical modification of cellulose is performed to improve processability and to produce cellulose derivatives (cellulosics) as carboxymethyl cellulose (CMC), methyl cellulose (MC), hydroxyethylcellulose (HEC), etc which can be tailored for specific industrial applications [3].

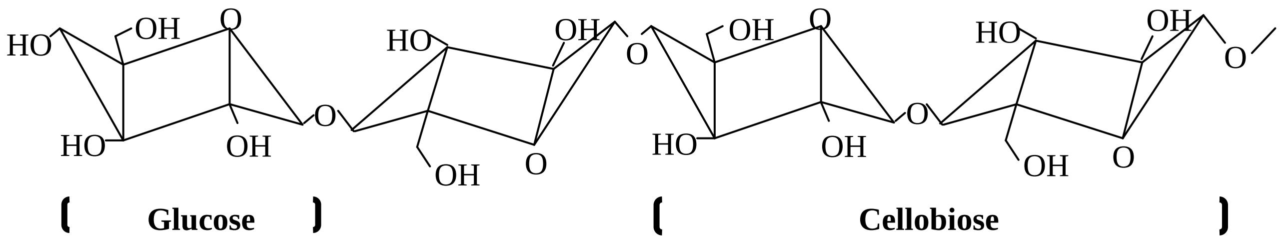

Fig.1: Molecular chain structure of cellulose [8]

Cellulose presents many application fields as cosmetic, medical, hygiene, food and drug industry (see Figure 5). The intramolecular bonds give stiffness to the polymer chain, while the intermolecular bonds allow the linear polymers to form sheet structures [7]. Because this biopolymer is abundant in nature, biodegradable and cheap, it can make it a promising nano-scale reinforcement material for polymers.

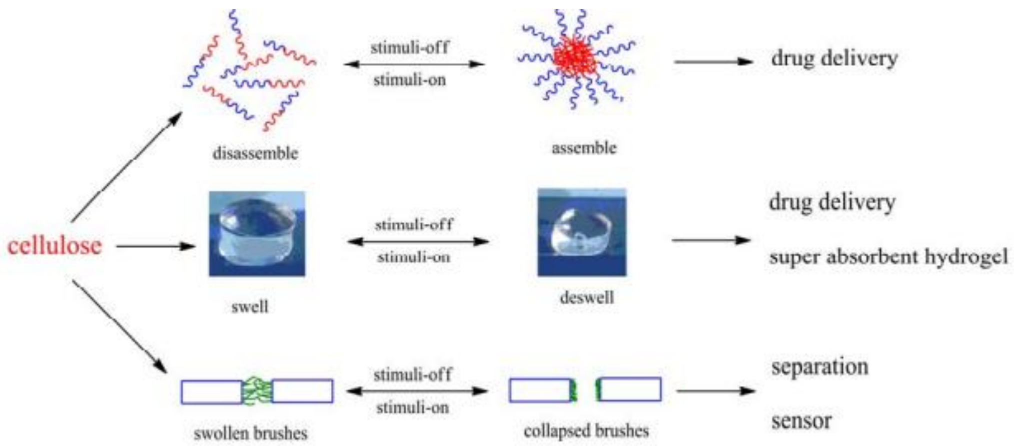

Fig. 2: Examples of “smart” materials based on cellulose and their possible applications [9]

II.2. CHITIN

Chitin is a natural polysaccharide of great importance. This biopolymer is synthesized by enormous number of living organisms and it belongs to the most abundant natural polymers, after cellulose [10].

Chitin is found in the lobsters, shells of crabs, insects and shrimps or can be generated via fungal fermentation processes.This biodegradable polymer occurs in nature as ordered crystalline microfibrils forming structural components in the exoskeleton of arthropods or in the cell walls of fungi and yeast [11].

The semi-crystalline structure of chitin microfibrils can be treated with acid to produce whisker-shaped nanofillers which can be incorporated into polymers to elaborate nano-hybrid materials [12, 13].

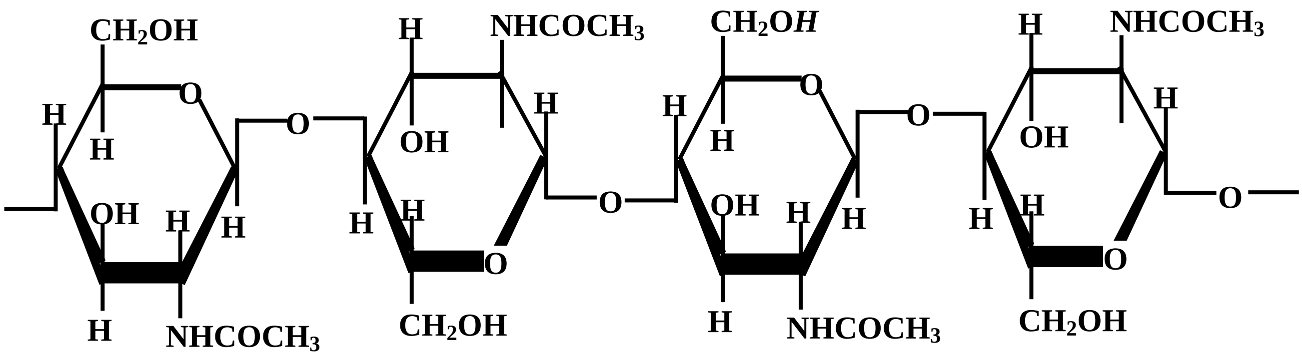

Fig. 3: Structure of Chitin [14]

Physical properties of chitin in solution cannot be analyzed correctly due to poor data caused mainly by difficulties in dissolution of this polymer. The dissolution is desired to estimate the molecular weight and to process chitin. Presence of aggregates in solution precludes light scattering measurements and overestimates the molecular weights [15].

Many properties of chitin have been already described such as: biocompatibility, renewable origin, non-toxicity non-allergenicity and biodegradability in the body. In addition, due to their attractive biological activities such as antifungal, antibacterial, antitumor, immunoadjuvant, antithrombogenic, anticholesteremic agent and bioadhesivity [16-17].

II.3. CHITOSAN

Chitosan is a polysaccharide obtained from chitin by deacetylation. This biopolymer is nontoxic and inexpensive and possesses reactive amino groups that has shown to be useful in different areas as an antimicrobial compound in agriculture, as a potential elicitor of plant defence responses, as an additive in food industry, as a hydrating agent in cosmetics, as a flocculating agent in wastewater treatment and more recently as a pharmaceutical agent in biomedicine [18].

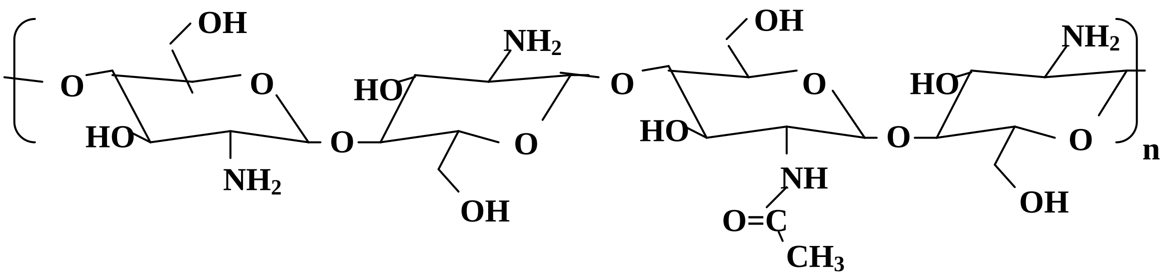

Fig. 4: Chitosan chemical structure [19]

For its biocompatibility chitosan is used in various medical applications such as implantation, antacid and antiulcer activities, potential carrier for drugs, biomedical applications and it also has antibacterial action [20].

Chitosan can selectively bind desirable materials such as cholesterol, fats, metal ions, proteins and tumor cells and it shown affinity for proteins, such as wheat germ agglutinin and trypsin [21].

II.4. GELATIN

Gelatin is a biomaterial based on animal proteins, it is a pure protein food ingredient prepared by the thermal denaturation of collagen. It appears slightly yellow and commercially solid as transparent, odorless, brittle and tasteless granule, sheets, flakes or powder, soluble in hot water, glycerol and acetic acid, and insoluble in organic solvents [22].

This natural polymer is derived from collagen and mostly found in fibrous tissues such as tendon, ligament, and skin. It is also abundant in cornea, cartilage, bone, blood vessels, gut, and intervertebral disc [23].

This natural polymer has been used for long years ago in pharmaceutical formulation, cell culture and tissue engineering due to its excellent biocompatibility, ease of processing and availability at low cost [24].

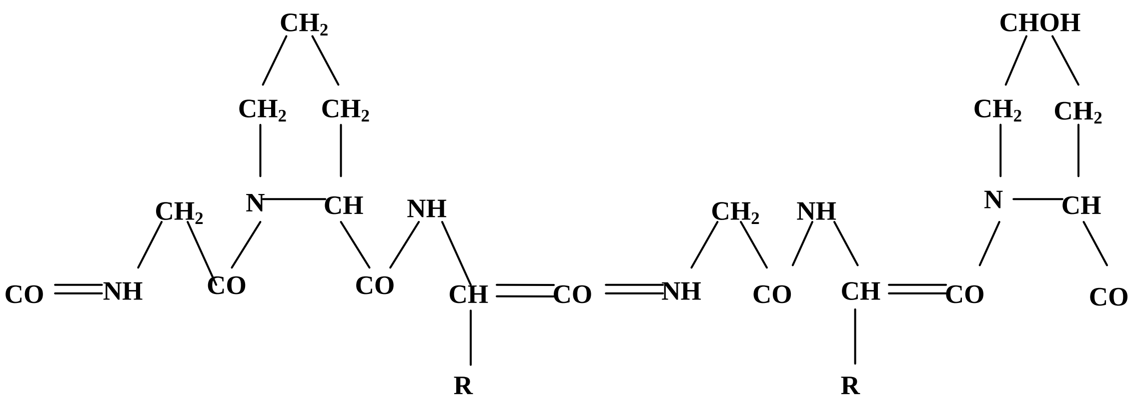

Fig. 5: Structure of Gelatin [22]

II.5.STARCH

Starch is a biopolymer which possesses many properties. It can be obtained from wheat, tapioca, maize and potatoes. Because it is a biodegradable polymer with well-defined chemical properties, it has a huge potential as a versatile renewable resource for various material applications in various areas [3].

Starch can be modified in such a method that it can be melted or deformed as thermoplastics.

Starch is mainly composed of two homopolymers of D-glucose : amylase, a mostly linear α- D(1, 4')-glucan and branched amylopectin, having the same backbone structure as amylose but with many α-1, 6'-linked branch points (see Figure 5) [25].

This biopolymer is the major carbohydrate reserve in plant tubers and seed endosperm where it is found as granules [26-27].

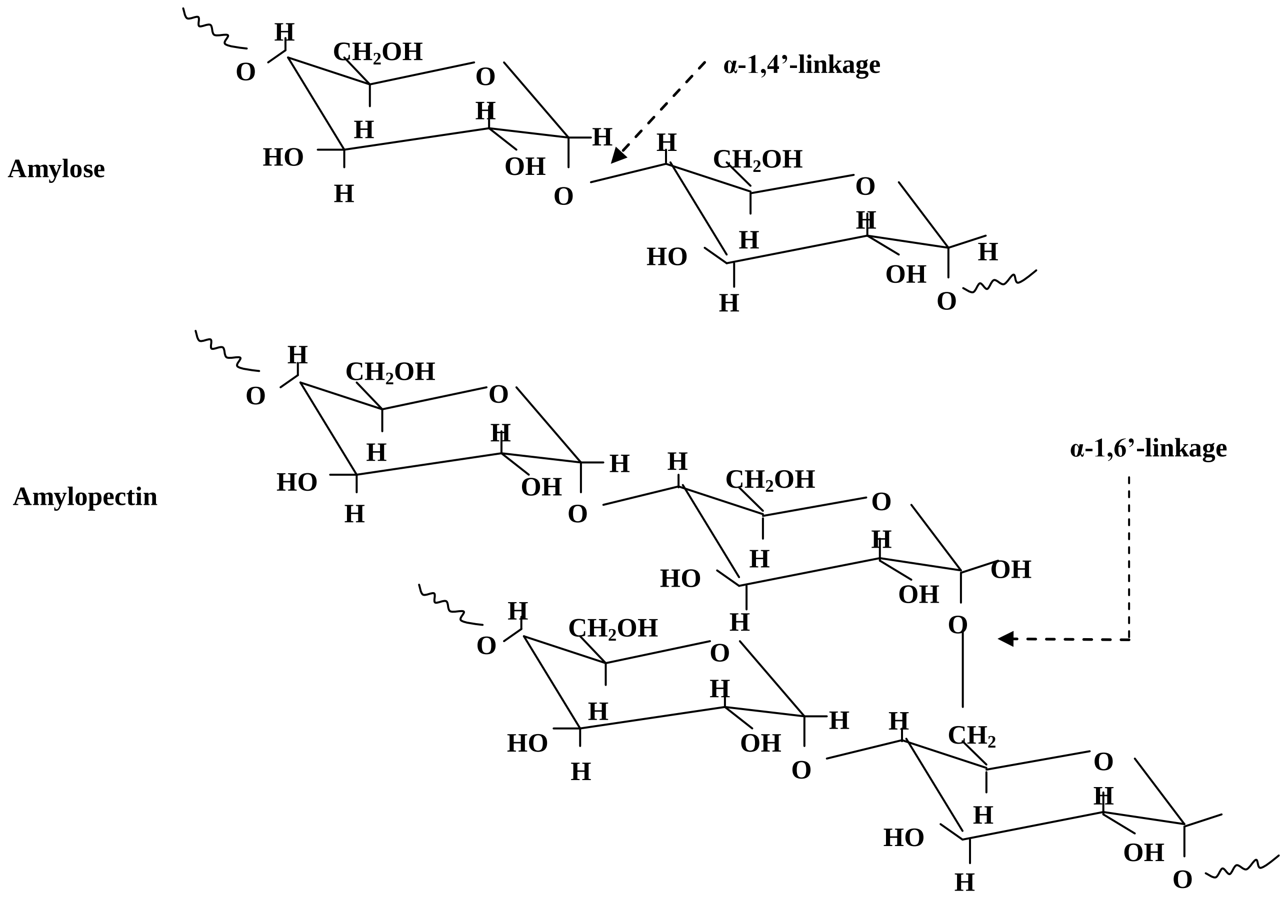

Fig. 6: Molecular structure of starch [25]

II.6. CARRAGEENAN

Carrageenan is a polysaccharide prepared by alkaline extraction from red seaweed (Rhodophycae), mostly of genus Chondrus, Eucheuma, Gigartina and Iridaea [28].

Carrageenans are linear polymers of about 25,000 galactose derivatives with regular but imprecise structures, dependent on the source and extraction conditions [29]. They are composed of alternating 3-linked -d-galactopyranose (G-units) and 4-linked -d-galactopyranose (D-units) or 4- linked 3,6-anhydrogalactose (DA-units), forming the ™ideal∫ disaccharide-repeating unit of carrageenans (see Figure 6).

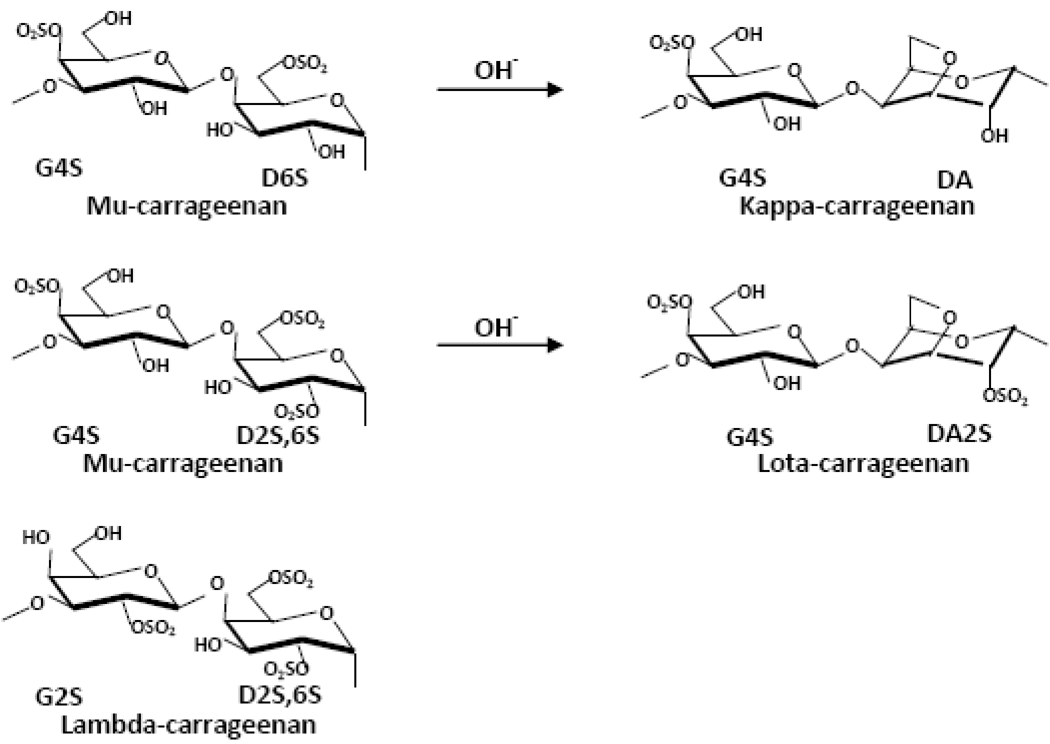

Fig. 7: Schematic representation of the different idealized repeating units of carrageenans. The letter codes refer to the alternative nomenclature [30]

Carrageenans are widely used in the food industry, for their gelling, thickening, and stabilizing properties. Their main application is in dairy and meat products, due to their strong binding to food proteins. There are three main varieties of carrageenan, which differ in their degree of sulphation. Kappa-carrageenan has one sulphate group per disaccharide. Iota-carrageenan has two sulphates per disaccharide. Lambda carrageenan has three sulphates per disaccharide [31].

II.7. XYLAN

Xylan is a biopolymer extracted from corn cobs.This hemicellulose largely found in nature has been used as an adhesive, thickener, and additive to plastics. It increases their stretch and breaking resistance as well as their susceptibility to biodegradation [32].

Xylan may also be found in the food industry as an emulsifier and protein foam stabilizer during heating [33].

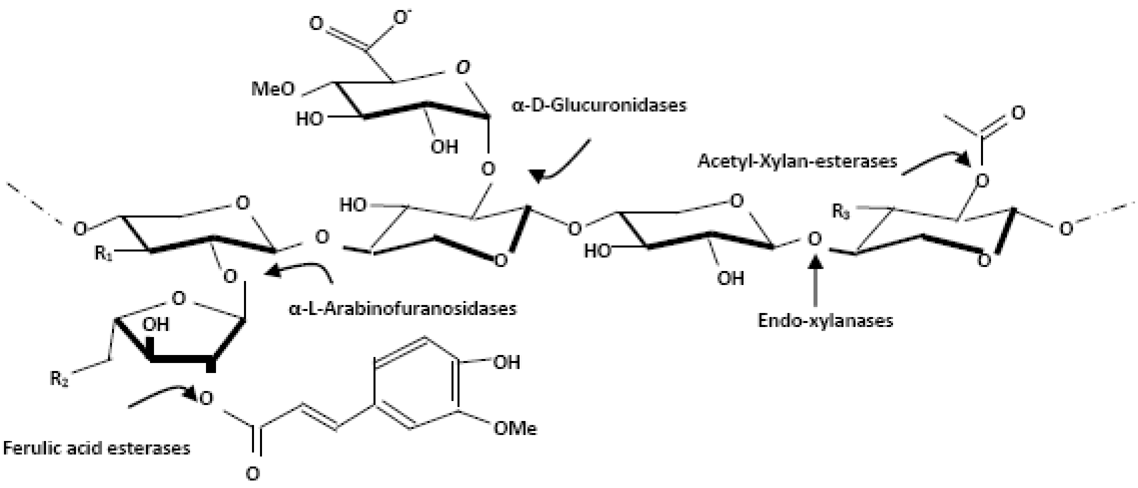

Fig. 8: Molecular structure of xylan [34]

Xylans can be used as pure polymers or relatively unpurified extracts containing contaminating and/or bound protein, phenolic substances, and other polysaccharides, that is dictated by the expected end uses as well as the production costs. As the most important application fields, the pulp and paper, food and pharmaceutical industries can be marked [35].

II.8. DEXTRAN

Dextran is a complex, branched polysaccharide made of many glucose molecules composed of chains of varying length (from 10 to 150 kilodaltons) [36]. This class of polysaccharides is composed of monomers of the simple sugar glucose and is stored as fuel in yeasts and bacteria [37].

Dextrans may be used in many important fields because they present natural products from renewable resources, excellent biocompatibility and clinical safety record and superior moisturizing properties.

The potential application of Dextran in ice-cream has been investigated . Recent studies have shown that glucose uptake by brush-border mucosa is enhanced after exposure to Dextran [38].

This natural polymer has been known for his viscosifying, emulsifying, texturizing, stabilizing attributes in food applications. It has the potential to be recruited as a novel ingredient replacing the commercial hydrocolloids in bakery and other food industries [39].

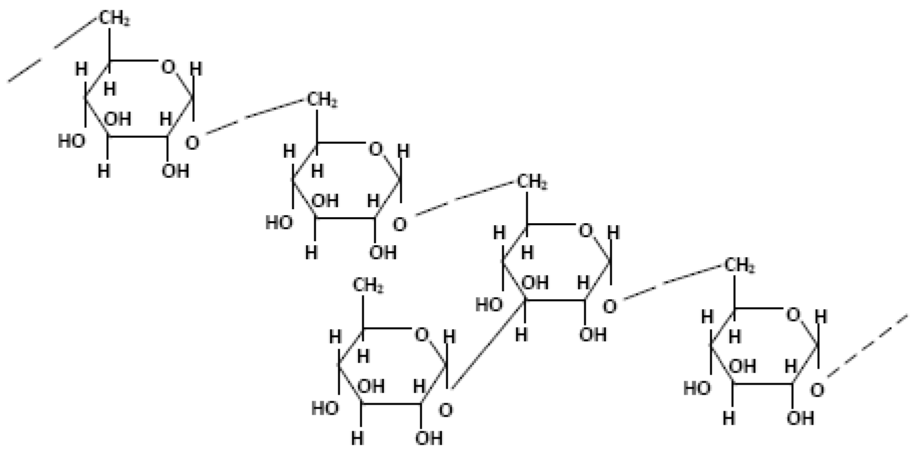

Fig. 9: Structure of Dextran [36]

III.CONCLUSION

This review details some biopolymers, their properties as well as their applications in various fields. Now-a-days natural polymers play a very important role in our life. Researchers and scientits have achieved a great success in developing new systems as nanotechnology with biopolymers.

In the other way, natural polymers have received much more attention in the last decades due to their potential applications in the fields related to environmental protection and the maintenance of physical health so we can say that biopolymers can be good substitute for the synthetic polymers and many of the side effects of the synthetic polymers can be overcome.

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F. Z. BENABID and F. ZOUAI, NATURAL POLYMERS: CELLULOSE, CHITIN, CHITOSAN, GELATIN, STARCH, CARRAGEENAN, XYLAN AND DEXTRAN, *Algerian J. Nat. Products,* 4:3 (2016) 348-357.

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