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ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN : 0974-4290
Vol.6, No.5, pp 3000-3003, Aug-Sept 2014

A Review on Industrial Applications of Curdlan

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Abstract: Curdlan, a bacterial exopolysacharide with linear chain of β (1→3) glucan is produced from non toxicogenic organisms *Alcaligenes faecalis* or *Agrobacterium radiobacter*. Curdlan is insoluble in water with excellent rehological behaviour and form thermo-irreversible high set gel. These properties have increased the demand for production of curdlan. They are required in various industries as texturizer, stabilizer, drug delivery vehicle, adsorbent, binder, etc., This review focus on importance of curdlan and its application in various industries.
Key words: Industrial Applications of Curdlan.

Introduction

Curdlan, a high molecular weight exopolysacharide is produced by gram negative bacillus *Agrobacterium* species (formerly known as *Alcaligenes faecalis* var.myxogenes). It was discovered by Harada and co-workers in the year 1966 (1). The microbe that produced a new β (1→ 3) glucan called as succinoglucan containing 10% succinic acid and also produced an alkali soluble β (1→3) glucan from a spontaneous mutant. Later on there was a pioneer development in the research and marketing of β (1→ 3) glucan in the trade name curdlan after the approval from U.S. Food and drug administration (2). Curdlan received its name because of its curdling nature in the presence of heat. Its production is aided with post stationary phase of nitrogen limited batch fermentation (3). On heating the aqueous suspension, the gel does not return to the liquid state and this property is considered to be very distinct among other polysaccharides (4). This polymer has gained its potential applications in both food and non-food industries because of its water insoluble, rheological and gelling properties. In this review, application of curdlan is studied in detail for its extended use in different industries.

Properties of Curdlan

Curdlan is unbranched polymer formed by repeating units of D-glucose linked by β-1, 3 glucosidic linkages. The average degree of polymerization (DP) is ~450 and its average molecular weight is in the range of 5.3×10^4 to 2.0×10^6 Da when dissolved in 0.3 N NaOH (5). Curdlan is insoluble in water and alcohols and soluble in aqueous alkali solution and DMSO.

Curdlan is widely utilized for its gel forming ability. The gels are of two types – low set and high set gels. The rheological and thermal behavior of high set and low set gels are reported by Zhang et al. 2012 (6). Aqueous suspension is heated up to 55 °C to form gel and on cooling they revert back to liquid. They are said to be thermo-reversible or low set gels. High set gels are formed when its aqueous suspension is heated above 75 – 80 °C and by consecutive cooling they do not return back to its original state on cooling. Hence they are known to be thermo-irreversible (7). This Characteristic feature of curdlan makes it unique from other gelling agents. It has stability in freeze- thawing conditions when compared to other gelling agents such as agar-agar and konjac. These properties make it a favorable candidate to be used in food industry as a stabilizing, thickener, texturizer and a firming agent (8).

Applications of Curdlan

Reports show that curdlan have numerous application in the field of medicine, pharmaceutical industries, food industries and in construction field. In 1966, this polymer gained its economical importance after gellan and xanthan and this became the third microorganism-fermented hydrocolloid.

Food Applications

Curdlan gained its major importance in food industry because of its rheological property due to this unique feature it is widely used as a bio-thickener. In the year 1966, US Food and Drug Administration (FDA) acclaimed curdlan for the use in food industries as processing aid, formulation aid, stabilizer and texturizing agent or thickener (5). In 1989, Japan set curdlan in markets due its exceptional properties. Commercially curdlan was accepted with little amount of inorganic salts, especially sodium chloride and largely glucose residues (2). Also, it is approved for its non-toxicity. Some of the major food products which use curdlan as their aids include jelly-like foods, edible fibers, noodles and also as immobilizing supports. In meat, dairy and baking industries it is used as a texturizer as it is tasteless, odorless and colorless and also because of its water holding capacity (9). Since curdlan is not reduced by certain digestive enzymes, it provides the possibility of new calorie-reduced products.

Medical Applications

Curdlan and its derivatives exhibit many potential applications in the field of medicine. The special biological property of this polymer includes anti-AIDS (Acquired Immouno Deficiency Syndrome) activity of its sulfate derivative and exemplary anti-viral activity of its glycidol derivative (10). Some of the curdlan derivatives have low toxicity and outstanding activity against blastomere infection (11), and this exemplary biopolymer can act as a latent supplementary therapeutic factor to treat malaria (3). Potions from 10 to 20 mg/kg body weight were analyzed to repress carcinomal diseases (12). In addition to this, the polymer also has a particular effect and generates a group of immune cells such as macrophages (15), neutrophils, monocytes, natural killer cells (6). They also have positive impact on many immune receptors including Dectin-1 (13), complement receptor (CR3) (14) and TLR-2/6. Also, there are innumerable research carried out to study their resultance on hypercholesterolemia, diabetes, glycemia along with their respective act on immunpotentiators and antitumorogenic agent (16,17).

Sulphated curdlan is a derivative of curdlan which is used to treat viral diseases and cancer because of its high fucose content. Fucose is a sugar molecule which is not easy to obtain in markets. Therefore, finding a polysaccharide derivative containing fucose or any other component such as fucopol is very useful as it has its potential to treat cancer and other inflammatory diseases (18).

Curdlan hydrogels which are formed by photopolymerization were used as a drug delivery vehicle for bioactive macromolecules. It can retard and control the diffusion of drugs to promote a more controlled release of the drug (19). In vitro drug releasing studies have also been carried out with curdlan gels containing bovine serum albumin as a model protein. Recent advances in our research field contributed much towards the improvement in therapeutic proteins, peptides, and oligonucleotides. This development has created a need for relevant drug delivery vehicles for transporting hydrophilic as well as hydrophobic bioactive macromolecules to

the targeted sites. Many reviewers have also reported that curdlan can act as a drug delivering vehicle as it has the ability to form gel on heating above 55 °C (19,20).

Further more, Curdlan is used in gel encapsulation of prednisolone, salbutamol sulfate and indomethacin in suppositories. This promotes supportive drug diffusion in the lower rectum thereby passing first pass metabolic deliverance by the liver when taken orally or by other routes of administration (21). Kanke et al has reported that the pharmacokinetics of theophylline is improved by co-spray drying of curdlan on to the theophylline encapsulated tablets (22).

Recent advances in the progress of polysaccharide-polynucleotide compounds as a therapeutic agent led to a new way of using curdlan in complexed form. This forms a structure which resembled much like the hydrogen bonding in the polypeptide chains of DNA and enables the rendition of the drug at the site of target. Curdlan complexed with polynucleotide polycytosine is experimentally proved to be used as a therapeutic agent (23). Solubilizing carbohydrate appendages are added to curdlan which enables curdlan to bind to polycytosin and they serve as an innovative pharmaceutical agent (24).

Solid lipid nano particles are produced when curdlan and cacao butter are combined with ammonium hydroxide and these nanoparticles are filled with the drug verpamil for drug rendition. This type of drug delivery is highly efficient compared to the conventional techniques. When hydrophilic polymer curdlan encapsulates cancer chemotherapy drug doxorubicin, it increases its stability for more than a year under frozen condition (25). Another application of curdlan is the conjugation of the carboxymethylated polymer to cholesterol.

Other Applications

Adsorbents using biopolymers are being developed recently because of their biocompatible nature compared to synthetic adsorbents. Curdlan in combination with activated carbon is used for adsorption of heavy metals by Moon et al. (2005) Adsorption studies were carried out for four different heavy metals such as Pb(II), Cd(II), Cu(II), and Mn(II). It was reported that addition of curdlan in the adsorption mixture helped in manipulating the pore size and the adsorption ability is increased by the addition of activated carbon. Optimum pore size was obtained by adjusting the activated carbon to curdlan ratio. In this study curdlan was observed to act as binder as well as an adsorbent because of the presence of hydroxyl groups (26).

A particular study reported the application of curdlan in the development of super workable concrete. This super workable concrete has excellent plasticity obtained as a result of increasing the viscosity of the slurry (27).

Conclusion

Unique physical properties of curdlan have set its importance in different industries. Therefore curdlan has a great demand and it can exert its highest potential in various applications. Further research in improving production of curdlan at cheaper rates may satisfy industrial needs.

Acknowledgement

We gratefully thank Department of Biotechnology, Government of India for its financial support for the execution of the project (Grant: BT/PR7511/BCE/8/973/2013).

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