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Review

Carrageenan: A natural seaweed polysaccharide and its applications

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ABSTRACT

Polysaccharides have been gaining interesting a[illegible]aluab[illegible]dication[illegible]he food and pharmaceutical fields. As they are derived from the natural so[illegible], they are ea[illegible]va[illegible]e, non-toxic, cheap, biodegradable and biocompatible. Carrageenan is on[illegible] them, which[illegible]s the criteria of polysaccharide; it is a natural carbohydrate (polysaccharid[illegible]obta[illegible]from edible r[illegible]d seaweeds. The name Carrageenan is derived from the *Chondrus crispus* species of sea[illegible] (Rhodophyceace) known as Carrageen Moss or Irish Moss, and Carraigin. A dema[illegible]t on its applic[illegible] has been widely increasing in food and pharmaceutical sectors. Carrageena[illegible]s gained wide applicat[illegible]ns in experimental medicine, pharmaceutical formulations, cosmetics, and [illegible]d industries. Through keen references of the reported literature on carrageenan, in this review, we [illegible]e described [illegible]ut carrageenan, its properties, extraction and refining, and its food and pharmaceuti[illegible]pplications.

Contents

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1. Introduction

Natural polymers and their application in the pharmaceutical industry are covered by the presence of synthetic polymers. Natural polymers are preferred above the synthetic as they are inert, safe, non-toxic, biocompatible, biodegradable, low cost, eco-friendly and abundantly available in nature (Guo, Skinner, Harcum, & Barnum, 1998). Probably one of the materials taking more benefit from these advantages is the polysaccharide family, which has been gaining interesting and valuable applications in the biomedical and specifically in biopharmaceutical field. Polysaccharides can be obtained from a number of sources including seaweeds, plants, bacteria, fungi, insects, crustacea, animals and even humans, and can be structurally tuned through genetic engineering (Colquhoun et al., 2001; Coviello, Matricardi, Marianecci, & Alhaique, 2007; D'Ayala, Malinconico, & Laurienzo, 2008; Kost & Goldbart, 1997; Laurienzo, 2010). The polysaccharide term gathers collectively quite diverse large carbohydrates that can be composed of only one kind of repeating monosaccharide (termed homopolysaccharides or homoglycans; e.g. starch, cellulose) or formed by two or more different monomeric units (heteropolysaccharides or heteroglycans; e.g. agar, alginate, carrageenan). The conformation of the polysaccharide chains is markedly dependent not only on th and ionic strength of the medium, particularly in the case o polyelectrolytes, but also on the temperature and the concentrat of certain molecules. Polysaccharides are divided into two su types: anionic and cationic polysaccharides. Seve nic and cationic polysaccharides are widely available i ture d have gained keen interest in food and pharmaceut ield.

Carrageenan, a naturally occurring anio polysaccharides extracted from certa ed s ed (Kirk & Othmer, 1992) of the Rhodophyceae ly (Chen, L & Dustan, 2002; Rees, 1969; Rochas, Rinaudo 1989; Sno , 1976; Stoloff, 1959), particularly from *chondrus* , *euchema*, *gigartina stellate*, *iridaea*, *hypnea*, *solie agardhiella* , *arconema* (Chen, McLachlan, Neish, & Shac n, 1973; Cheney, ston, & Brailey, 1987; Chiovitti et al., 19 McCa es, West, & Guiry, 1982, 1983; Mollet, Rahaoui, & Lem 19 Mollion, 1983; Murano, Toffanin, Cecere, Rizzo, & Knutsen ; Parek Garg, Mehta, & Mehta, 1979; Parekh, & o, & C an 8; Parekh, Rao, & Chauhan, 1988). The "ca geenan is to originate from the inhabitants of count f carragheen, on the south Irish coast where extracts fr d and medicines were already used as early as 6 ars ago. The major constituent of such algae is the so-called geenans, co-polysaccharides with the linear backbone built up b -D-galactose and 3,6-anhydro-α-D-galactose with variable density in the sulfated group (Campo, Kawano, da Silva, & Carvalho, 2009). *Chondrus crispus*, *Gigartina stellata*, *Iridaea* spp., *Eucheuma* spp. and *Kappaphycus* spp. (Fig. 1) are the chief raw materials used for carrageenan extraction.

Ideally, each disaccharide in the chain contains a β-delta-galactopyranose (G-unit) with either α-delta-galactopyranose (D-unit) or 3,6-anhydrogalactose (DA-unit). Other carbohydrate residues commonly exist in carrageenan, such as xylose, glucose, and uronic acids. The disaccharide units are variably sulfated, resulting in a sulfate content of 22–38% by weight in commercial carrageenan (Van de Velde & De Ruiter, 2002). Other cations, such as ammonium, calcium, magnesium, potassium, and sodium, are also often present in the form of galactose esters (FAO, 2007; U.S. Pharmacopeia, 2010). Carrageenan is a good source of soluble fibre (Burtin, 2003). There are several different carrageenans with slightly varied chemical structures and properties (McHugh, 2003). The three most prevale ighest commercial interest, polysaccharides of carra nan are kappa, and lambda carrageenan, serving differ roperties (2007; U.S. Pharmacopeia, 2010; Van de Velde & D iter, 2002 S Food and Drug Administration have "G rally Re ized afe" (GRAS) list of products for consu ion an topic cations of carrageenan. Carrageenan i extre versatil gredient suitable for use in food and non i stries (Van de Velde, Lourenco, Pinheiro, & Bakke 002). geena s no nutritional value, but have been ely used in f industry (Heertje, 1993; Hood & Allen oeren, 197 aisgood, 1982; Van de Velde et al., 2002) nd mo cently used in the pharmaceutical industry as excipient in pill tablets (Campo et al., 2009) and as a pote materials of hy gels (Hoffman, 2002). In pharmaceuti applications (Takamatsu & Tosa, 1993; Van de Velde et al., 20) and expe ental medicine, carrageenan is often used for the ting of an nflammatory agents (Zacharopoulos & Phillips, 199

The al activity of carrageenan as a natural occurring saccharide has been increasing widely for human applications s a strong position in the biomedical field. Due to their ifferent chemical structure and physical properties this natural source can be used in the different applications, varying from tissue engineering to the preparation of drug vehicles for controlled release. This review article is prepared in order to focus on the present use and the diversified applications of carrageenan in pharmaceutical and food sectors.

2. Short summary on types, structure and properties of carrageenans

There are several different carrageenans with slightly varied chemical structures and properties (McHugh, 2003). Carrageenan formed by alternate units of D-galactose and 3,6-anhydro-galactose (3,6-AG) joined by α-1,3 and β-1,4-glycosidic linkage. According to the literature survey, carrageenan can be classified in 3 ways, based on the amount and position of sulphate groups, based on their family and based on its properties. Depending on the amount and position of the SO_3^- groups carrageenan are classified into λ(lambda), κ(kappa), ι(iota), υ(nu), μ(mu), θ(theta) and ξ(Ksi), all containing about 22–35% of sulphate groups (Stanley, 1987). Based on the family, Greer and Yaphe (1984) classified carrageenan mainly into three types as shown in the Table 1 (Anderson, Campbell, Harding, Rees, & Samuel, 1969; Glicksman, 1979; Hoefler, 2001; Hoffmann, Russell, & Gidley, 1996; Imeson, 2000; Moirano, 1977; Rees, 1969). The first family involves *kappa* (κ) family which contain a subclass like Kappa, iota, mu and nu carrageenan. The second class of family involves *lambda* carrageenan which, contain subclass like lambda, Xi and pi and the third class involves *beta* family containing subclass like beta and gamma carrageenan. Whereas Mollion, Moreau, and Christian (1986) introduced another family named *omega* family in which sulphate groups are on the C_6 of the 1,3-1, linked galactopyranosyl units. Alpha carrageenan was included as a subclass in beta family