Arabian Journal of Chemistry (2013) **xxx**, xxx–xxx

King Saud University

Arabian Journal of Chemistry

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ORIGINAL ARTICLE

Radiation-induced degradation of sodium alginate and its plant growth promotion effect

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Received 3 July 2012; accepted 4 October 2012

KEYWORDS

Irradiation;
Degradation;
Sodium alginate;
Growth promotion;
Faba bean plant

Abstract Alginate was irradiated as a solid with ^{60}Co gamma rays in the dose range of 20–100 kGy to investigate the effect of radiation on alginates. One of the principle factors for reducing the cost is achieving the degradation at low irradiation doses which occurs with addition of chemical initiator to NaAlg during irradiation process that leads to a synergistic effect, which remarkably increases the degradation efficiency of alginate. The factors affecting the degradation process such as irradiation dose and potassium per-sulfate (KPS) addition were studied. The average molecular weight of the irradiated alginate was investigated in detail by using several complementary techniques such as chromatography and viscometry. The lowest molecular weight of alginate resulted at 100 kGy and added KPS, whereas the highest one at 20 kGy in absence of KPS. Characterization of the oligoalginates obtained by radiation degradation was performed by FT-IR and UV–vis spectroscopy, XRD and TGA. The effect of water-soluble radiation-induced alginate fractions on the growth promotion of Faba bean plant was studied. The highest plant growth and seed yield compared with control occurred for plants sprayed with low molecular weight NaAlg fractions (treated with 100 kGy and added KPS).

1. Introduction

Alginate is a natural polysaccharide with a large available quantity in nature. It has widespread applications in the food and drink, pharmaceutical and bioengineering industries (Gacesa, 1988). Alginate is the sodium salt of alginic acid, the structural component of the algal tissue of Phaeophyceae, a class of brown seaweeds (Craigie et al.,1984; Avella et al., 2000). It is a copolymer composed of b-D-mannuronate (M) and a-L-guluronate (G) residues organized into blocks of homo-polymeric segments of MM or GG and alternating sequences of M and G. While the M-block segments develop in linear and flexible structures, the G-block residues give rise to fold and rigid structures and are responsible for a pronounced stiffness in the molecular chains (Fig. 1). Modification by crosslinking, grafting and degradation of alginates is expected to widen their application. The alginate oligomer fractions with the degree of polymerization from tetramer to hexamer have been reported to show a special growth-promotion effect for plant (Iwasaki and Mastsubara, 2000).

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Peer review under responsibility of King Saud University.

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http://dx.doi.org/10.1016/j.arabjc.2012.10.003

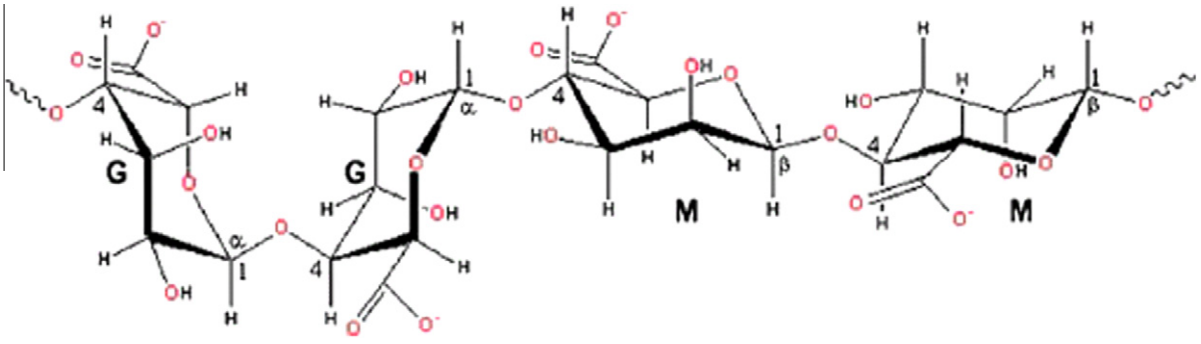

Figure 1 NaAlg chain sequence.

Degradation of alginates can easily be carried out by chemical, enzymatic hydrolysis or by using radiation.

Radiation is a very convenient tool for the modification of polymer materials through degradation, grafting and crosslinking. Recently, radiation effects on polysaccharides such as chitosan, sodium alginate, carrageenan, cellulose, pectin have been investigated to enhance their use for recycling these bioresources and reducing the environmental pollution. These polysaccharides were degraded by radiation and the biological activities such as anti-microbial activity, promotion of plant growth, suppression of heavy metal stress, phytoalexins induction, etc. were induced. Polysaccharides and their derivatives exposed to ionizing radiation had been long recognized as degradable type of polymers (Huang et al., 2007). Jaroslaw et al. applied three radiation degradation methods: ultrasonic, ultraviolet and gamma irradiation to sodium alginate and chitosan in aqueous solutions, the changes in molecular weight were monitored by GPC measurements (Jaroslaw et al., 2005). It has been found that from the energetic point of view the most effective method for polymers is gamma radiation method. The significant advantages of gamma radiation degradation are the final biological sterilization of irradiated materials that can be easily used for manufacturing biomedical products (Rosiak et al., 1995; Clough, 2001) and the ability to promote changes reproducibly and quantitatively, without the introduction of chemical reagents, and without special needs to control for temperature, environment and additives (Charlesby, 1977). Degradation by radiation processing of polysaccharides has gained much attention due to its technological effectiveness in producing low molecular weight oligomers (Luan et al., 2003) which have concrete application not only in the biomedical field but also in agriculture, as a plant growth promoter.

Applying ionizing radiation to degrade natural bioactive agents and then using them as growth promoting substances is a novel emerging technology to exploit the full genetic potential of crops in terms of growth, yield, and quality. Polysaccharides, such as sodium alginate, have been used as wonderful growth promoting substances in their depolymerized form regarding various plants (Nagasawa et al., 2003). The sodium alginate irradiated by gamma rays, has growth promoting activities like other plant growth promoters and acts as bio-fertilizer (Mollah et al., 2009). Depolymerized sodium alginate showed various biological effects on plants including enhanced seed germination, shoot elongation, and root growth (Yonemoto et al., 1993; Natsume et al., 1994; Hu et al., 2004).

In the present work, degraded alginate is prepared by exposure of alginate as a dry powder to γ-rays from Co-60 radiation and added KPS initiator. The effects of oligomers obtained from radiation depolymerized alginates on the growth-promotion of some Faba bean plants are examined.

2. Experimental

2.1. Materials

Sodium alginate, of high molecular weight was supplied from Nice lab, India. Potassium per-sulfate (98%) was purchased by British Drug House (BDH) Limited, England. Faba bean seeds were supplied from Advanced Group, Export & Trading, for the production of seeds and agricultural crops, Egypt.

2.2. Preparation of degraded alginate

Degraded NaAlg was prepared by exposing it in the powder form to γ-irradiation ^{60}Co source at different doses ranged from 20 to 100 kGy in the presence of KPS as chemical initiator at dose rate, 6.6 kGy/h.

2.3. Determination the molecular weight of degraded alginate

The weight-average molecular weights of the degradable alginates were determined by two methods:

2.3.1. Viscosity measurement

The weight average molecular weight of polymers was calculated with determination of viscosity of polymeric materials on the basis of the Mark–Houwink equation (Ghosh et al., 2009):

$$[\eta] = KM^{\alpha} \quad (1)$$

where $[\eta]$ is the intrinsic viscosity, K and α are constants the values of which depend on the nature of the polymer and solvent as well as on temperature and M is usually one of the relative molecular weight averages.

With known values for α and K it is easy to take the values from an intrinsic viscosity experiment $[\eta]$ and calculate average molecular weight (M). The molecular weight of sodium alginate can be determined by measuring the intrinsic viscosity of polymer in 0.01 M NaCl solution taking $K = 8.1 \times 10^{-3}$ ml/g and $\alpha = 0.92$ (Lui et al., 2002).

2.3.2. Gel permeation chromatography (GPC) method

Gel permeation chromatography of un-irradiated and irradiated samples was performed on an 1100 Agilant instrument

Please cite this article in press as: El-Mohdy, H.L.A. Radiation-induced degradation of sodium alginate and its plant growth promotion effect. Arabian Journal of Chemistry (2013), http://dx.doi.org/10.1016/j.arabjc.2012.10.003