12. Radiation Degradation of Alginate and Some Results of Biological Effect of Degraded Alginate on Plants

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Abstract

Radiation degradation yields (Gd) of alginate in aqueous solution with different concentration were determined by viscometry method. The relationship between Gd and the alginate concentration was found out as: $Gd = 33.5 \times C^{-0.68}$, with C% (w/v) and dry alginate referred to C=100%. An empirical equation for preparing degraded alginate with the desired low viscometry average molecular weight (Mv) by radiation was proposed. Alginate extracted directly from seaweed'*Sagassum*, degraded by radiation was used for field experiments and results of the biological effect on plants (tea, carrot, chrysanthemum) were presented.

Keywords: Alginate, Radiation Degradation Yield, Plant Growth-Promotion

1. Introduction

Sodium alginate, a salt of alginic acid, one kind of marine polysaccharides with largely available quantity in nature, is produced mainly from brown seaweeds. According to Gacesa (1988), annual alginate production is about 15,000 tonnes, processed from 400,000 tonnes wet weight of seaweed [1]. In Vietnam, brown seaweed is estimated to be about 30,000 tonnes wet weight per year and grown mainly in the seashore area of the middle country [2].

Alginates are widely used in food, cosmetic, pharmaceutical and bioengineering industries [1]. The degradation of alginate by radiation has recently been of our research interest and the irradiated alginate exhibits the significant effect of the growth-promotion on plants [3,4].

This paper deals with the radiation degradation of alginate in aqueous solution with different concentrations and the biological effect of irradiated alginate on plants.

2. Preparation of radiation degraded alginate

2.1. For fundamental study

Sodium alginate with Mv_0 = 336,000 was a product of Kishida Chemical Co., Japan. Alginate solution with concentrations of 2; 4; 6; 10% (w/v); and 100% (dry alginate) was prepared as described previously [3], and alginate samples were irradiated by gamma rays from a Co-60 source with dose rate of 2kGy/h, at room temperature. The changes of viscometric average molecular weight (Mv) of alginate were determined by the viscometry method using an Ubbelohde viscometer at 25°C, in 0.1M NaCl solution. The Mv was calculated based on the Mark-Houwind equation: $[\eta] = k. Mv^{\alpha}$ (1), with k=7.3 x 10^{-3} ml/g and α=0.92 [5]. The radiation degradation yield (Gd) was calculated based on the equation (2) [6]:

$$(1/Mv - 1/Mv_0) = Gd \times 1.04 \times 10^{-7} \times D(kGy) \qquad (2)$$

These degraded alginates were used for studying the growth-promotion effect on rice and coriander in green house for a short growing period after germination [7].

2.2. For field experiments

Brown seaweed' *Sargassum* (*glaucescens, incanum, hemiphyllum, duplicatum, mcclurei,..*) was supplied by the seaweed factory of the Institute of Oceanography Nha trang, and used as starting materials for extracting alginate. The extracted alginate solution with concentration of 5% (w/v) was irradiated with gamma Co-60 radiation at the dose of 100kGy to prepare low molecular weight alginate. This degraded alginate was used for field experiments on some kinds of plant such as tea, carrot and chrysanthemum as a plant growth-promoter [7].

3. Results and Discussion

3.1. Radation degradation of alginate

The relationship between the alginate concentration and the radiation degradation yield was shown in Fig. 1. Based on the data in Fig.1, an equation fitted for the curve was ruled out as :

$$Gd = 33.5 \times C^{-0.68} \qquad (3)$$

From equations (2) and (3), in order to obtain the degraded alginates with desired low Mv by radiation, the following equation was proposed:

$$Mv = Mv_0 / [(Mv_0 \times 33.5 \times C^{-0.68} \times D(kGy) \times 1.04 \times 10^{-7}) + 1] \qquad (4)$$

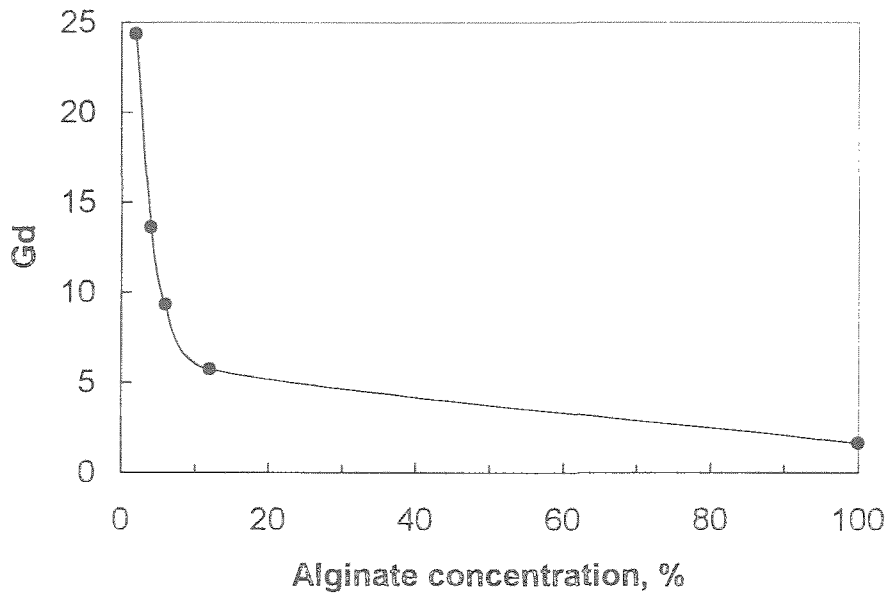

Fig. 1. The relationship between the alginate concentration and Gd

For example, the alginate extracted from Vietnam brown seaweeds having Mv_0 = 25,000, C (%) = 5 and D(kGy) = 100, then it can be ascertained that Mv of the degraded alginate will be of about 6,400. This estimated result according to equation (4) was in good agreement with the results measured by HPLC method, particularly Mw = 6,500 and Mn = 5,000 (Mw/Mn = 1.3). However, it is worth to note that the distribution or the homogeneity of the absorbed dose in the irradiation volume is the most important factor to apply the above mentioned equation for calculating molecular weight of irradiated alginates.

2.3. Biological effects on plants

2.3.1. The effect of alginate molecular weight on the growth-promotion

Results in table 1 indicated that alginate sample having the highest effect of plant growth-promotion depends on the molecular weight of alginate. In this experiment, the alginate sample with Mv of about 7,000 was the most effective. The obtained results confirmed ones again the growth-promotion effect of the radiation degraded alginate for plants reported previously [3].

Table 1. The growth-promotion effect of the irradiated alginate on rice and coriander

Dose kGy	Mv	Dry-matter			
		Rice		Coriander	
		g/100plants	%	g/100plants	%
blank	-	2.07	100	0.431	100
0	336,000	2.36	113.8	0.477	110.5
30	21,600	2.51	121.0	0.521	120.7
60	12,000	3.14	151.5	0.527	122.4
100	7,000	3.64	175.5	0.605	140.2
150	4,700	2.55	123.2	0.514	119.1
	$LSD_{0.05}$	0.34	12.4	0.025	4.9

Alginate concentration: 40ppm, treated after 3 days germination, and harvested after 5 days

2.3.2. The growth-promotion effect on plants in field

Table 2. The growth-promotion effect of the irradiated alginate on tea

Alginate conc. (ppm)	Bud density (buds/m^2)	%	Bud weight (g/100buds)	%	Bud yield (kg/ha)	%
0	76.6	100	128.6	100	535	100
25	83.6	109.3	131.1	102.5	591	110.5
50	91.1	119.0	132.2	102.8	632	118.1
100	93.5	122.1	134.4	104.5	639	119.4
200	80.2	104.7	130.0	101.1	574	107.3
$LSD_{0.05}$	3.1	3.6	2.5	1.9	25	4.2

Results in table 2 showed the remarkable effect of the growth-promotion of the irradiated alginate on tea (*Camellia sinnensis van Shan* TB-14). In the range of alginate concentrations from 25 to 200ppm, the treatment of 100ppm attained the highest increase of bud density (22.1%), bud weight (4.5%), and finally bud yield (19.4%). In addition, the quality of tea buds was improved through the higher content of soluble substances (18.7%) and tannin (28.1%) compared with that of the control (not treated with the irradiated alginate).

As can be seen in table 3, the irradiated alginate also showed the strong effect of the growth-promotion on carrot (*Daucus carota L.*). In the range of alginate concentrations from 20 to 200ppm, the treatment of 60ppm reached the highest increase of the root yield (60%) while the biomass of leaves was not significantly different. Furthermore, the quality of the carrot root was also improved through higher reduced sugar and lower nitrate content (see table 3), while the dry matter content remained almost unchanged.

Table 3. The growth-promotion effect of the irradiated alginate on carrot

Alginate conc. (ppm)	Leaf yield (kg/ha)	Root yield		Contents					
				Nitrate		Reduced sugar		Dry-matter	
		kg/ha	%	mg/kg*	%	g/kg*	%	%*	%
0	21,114	35,583	100	615±17	100	6.29±0.18	100	8.7±0.8	100
20	27,333	46,913	131	491±29	79.9	7.26±0.52	116	8.8±0.6	101.2
40	26,469	50,686	142	458±17	74.5	8.25±0.71	131	8.9±0.2	102.7
60	29,589	57,315	160	448±26	72.9	8.64±0.34	137	9.1±0.6	104.5
80	28,425	52,845	148	446±19	72.6	9.02±0.41	143	9.1±0.1	104.4
100	25,290	47,190	132	451±50	73.4	10.37±0.74	165	8.9±0.7	102.4
200	26,007	46,995	131	453±12	73.7	10.02±0.29	159	8.6±0.6	99.5
$LSD_{0.05}$	NS**	4288	9						

** For fresh matter, ** None significant difference*

Table 4 presented the growth-promotion effect of the irradiated alginate on chrysathemum (Yellow nobita) in the range of the concentration from 20 to 200ppm. Of seven treatments, the treatment of 80ppm attained the highest increase of shoot height (25.9%), leaf number (13.7%, data not shown), flower diameter (10.4%) and finally the weight of flower shoots (48.4%).

Table 4. The growth-promotion effect of the irradiated alginate on chrysanthemum

Alginate Conc. (ppm)	Flower characteristics					
	Shoot height		Flower diameter		Flower shoot weight	
	cm	%	cm	%	kg/10shoots	%
0	87.6	100	3.7	100	1.15	100
20	97.4	111.2	3.8	103.2	1.29	112.5
40	100.0	114.2	3.9	104.3	1.36	118.6
60	104.9	119.8	3.9	105.8	1.50	130.1
80	110.3	125.9	4.1	110.4	1.71	148.4
100	101.4	115.8	3.8	103.8	1.38	120.3
200	98.4	112.4	3.8	103.4	1.33	115.5
$LSD_{0.05}$	7.4	7.4	0.1	2.8	0.17	12.2

The toxicity of the radiation degraded alginates either from pure alginate or alginate extracted directly from brown seaweed was evaluated at the Vaccine Institute, Dalat. Results indicated that both the irradiated alginates were none toxic.

3. Conclusions

According to the results of the growth-promotion effect and toxicity tests, it can be concluded that the radiation degraded alginate can be considered as a wholesome specific growth-promoter for plants.

References

[1]. Gacesa, Alginates, *Carbohyd. Polym.*, 8, 161-182 (1998).

[2]. Nguyen Huu Dai, *Sargassaceae* in Vietnam: Resource & Utility (in Vietnamese), Agri. Pub. House, Ho Chi Minh City (1997).

[3]. Ng. Q. Hien, N. Nagasawa, L. X. Tham, F. Yoshii, V. H. Dang, H. Mitomo, K. Makuuchi and T. Kume, Growth-promotion of plants with depolymerized alginates by irradiation, *Rad. Phys. Chem.* (submitted).

[4]. Ng. Q. Hien, L. Hai, V. T. Thien, T. T. Hanh, L. Q. Luan, Study on radiation degradation of alginate for production of oligoalginate, *Vietnamese J. Chem.*, 36 (4), 19-23 (1998).

[5]. A. Matisen, G. Skjak-Brak, O. Smirod, F. Zanetti, S. Paoletti, Comparision of different methods for determination of molecular weight and molecular weight distribution of alginates, *Carbohydr. Polym.*, 15, 171-193 (1991).

[6]. A. Charlesby, Atomic radiation and polymers, Pergamon Press (1960).

[7]. L. Q. Luan, M. Sc. Thesis, Dalat University, Vietnam (1998).