

LOW MOLECULAR WEIGHT XANTHAN PREPARED BY GAMMA IRRADIATION AND ITS EFFECTS ON DEVELOPMENT OF SEEDLINGS

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Abstract: Low molecular weight (M_w) xanthan was prepared by gamma Co-60 irradiation at both dry and paste-like states. The viscosity average molecular weight (M_v) of the irradiated xanthan gradually decreased with the increase of the radiation dose. Its M_v slowly reduced to 1.8×10^3 kDa from 1.1×10^4 kDa of non-irradiated xanthan by irradiation at 500 kGy in the solid state, and quickly reduced to 5.3×10^2 kDa by irradiation at 50 kGy in the paste-like state. However, the viscosity of the xanthan is still high enough for utilization as a bio-adhesive polymer. Therefore, the low M_w xanthan prepared by gamma irradiation has been studied as the additive to improve the effectiveness of fertilizer. In this study, foliar fertilizers supplemented with xanthan and irradiated xanthan were applied to maize and soybean seedlings. The results suggested that their developments were much increased by the presence of irradiated xanthan compared to initial xanthan, as indicated by the increases of their plant height, root length and fresh biomass.

Key words: Xanthan, gamma radiation, degradation, foliar fertilizer, seedling

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1. INTRODUCTION

Xanthan is usually produced by *Xanthomonas campestris* through bacteria fermentation. Being a natural polysaccharide with very high viscosity and molecular weight, xanthan has been widely used as food additives, especially for food preservation and processing due to its abilities to alter water flow and gel formation. Though it is not able to form a gel, the addition of xanthan gum may be applied as bio-adhesive agent to reduce the amount of oil in food products, resulting in not only better microbiological stability, but also leading to healthier products [1-3]. It can also be utilized as the carrier for agrochemicals or plant protectors in order to facilitate their adhesion and remain in plant leaves [2].

In normal conditions, it hardly to be prepared as aqueous solution because of its high viscosity at even low concentration. This viscosity somewhat limited its application. However, the viscosity of xanthan may be decreased by depolymerization or decomposition like other natural polysaccharides. Some methods were applied to produce low molecular weight (M_w) xanthan for further applications [4]. Among them, radiation degradation has been proved as one of the most effective and useful tool. Depended on radiation dose and dose rate, viscosity and M_w of the irradiated xanthan will reduce to some extent. Study on radiation degradation of xanthan in solid state, M. Şen et al

reported that the M_w reduction was more effective by gamma irradiation at low dose rate [5].

By gamma irradiation of xanthan in solution, Li Yan-jie *et al* [6] have reported that M_w of the xanthan was reduced to half by gamma irradiation at a low dose of 5 kGy, but its M_w distribution become wider with the dispersity index of about 20, much influenced on its properties. They also reported that low M_w xanthan with the average molecular weight below 10 kDa can be prepared by gamma irradiation at a dose of 120 kGy.

On the other hand, high viscosity of this low M_w xanthan makes it become potential bio-adhesive, which can be applied to reduce the loss of chemical fertilizers and enhance the crop yields. Though chemical fertilizers have an important role for our agriculture, they also contaminated our planet because more than 50% NPK fertilizer did not uptake by plants. Therefore, new effective fertilizers such as organic fertilizers, foliar fertilizers... are being developed to replace chemical fertilizers [7-9].

Polysaccharides and their derivatives were studied as plant promoters, elicitors or stimulators, but their high molecular weight somewhat limited to the uptake of plants [10]. Recent years, gamma irradiation has been proved as a useful way to degrade polysaccharides to produce low M_w or oligo-saccharides. Radiation degradation may improve bioactivity of the irradiated products because its functional groups seemed not to be affected during radiation. In our previous study, various low M_w chitosan fragments have been

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prepared by gamma radiation for utilization as anti-microbial agents in food preservation and textile.

In this study, both xanthan in powder and solution states were gamma irradiated under Cobalt-60 source. The radiation effects on viscosity and Mw of xanthan were investigated with radiation dose. The xanthan solutions of various concentrations were supplemented to the foliar fertilizer, which applied to the maize and soybean for investigation of their effects on the developments of seedlings.

2. EXPERIMENTAL

2.1. Materials

Xanthan is a China product which was purchased from BaDinh technology Co. NI-PHOS-KA foliar fertilizers was kindly supported by NamBac Co. (Vietnam). All of the other chemicals were bought from Wako Pure Chemicals.

2.2. Radiation treatment

Xanthan was dissolved in distilled water to an aqueous solution of ~2.5%. Both xanthan powder and solution were irradiated under Co-60 source at Hanoi Irradiation Center with dose ranges of 10-500 kGy and 10-50 kGy for solid and liquid states, respectively.

2.3. Measurements

The polymer solutions were prepared in 0.1 M KCl as solvent and their relative viscosities were measured for estimate their intrinsic viscosity and viscosity average molecular weight. Relative viscosity (η_r) of the xanthan solutions was calculate as the ratio of flow times of a xanthan solution to pure solvent through capillary viscometer at 25°C. Its intrinsic viscosity $[\eta]$ was obtained by extrapolating its reduced viscosity ($\eta_{red} = (\eta_r - 1)/c$) when the polymer concentration reduces to zero. $[\eta]$ value in dL/g can be determined as the intercept of linear relationship between η_{red} and polymer concentration (c). The viscosity average molecular weight of xanthan (M_v) was calculated with the following equation [11]:

$$[\eta] = k_m \times M_v^a \text{ (mL/g)} \quad (1)$$

where $k_m = 1.7 \times 10^6$ dL/g, $a = 1.14$, respectively [5]

Different xanthan samples were admixed to the foliar fertilizers at 50 and 100 ppm to prepare the spraying solutions, which applied to maize and soybean seedlings. After a predetermined period from spraying, the effects of xanthan on the plant growth were investigated as the changes in the plant height, root length and fresh biomass of the seedlings.

3. RESULTS AND DISCUSSIONS

3.1. Change in viscosity and viscosity-average molecular weight (M_v) of irradiated xanthan

By radiation treatment, the solubility of irradiated xanthan much increased and the time required for dissolving the irradiated xanthan gradually reduced

with increasing of radiation dose. For the xanthan irradiated in powder, its relative viscosity quickly decreased with radiation dose to 100 kGy, then slowly decreased with further increase of radiation dose, but it was high enough for the application as a bio-adhesive. The same tendency was also observed for the xanthan irradiated in solution (the data not shown).

As can be seen from Fig. 1 and Fig. 2, viscosity average molecular weight (M_v) of the initial xanthan was significantly decreased by gamma radiation. This reduction can be divided into two steps. First, initial M_v above 1000 kDa quickly reduced to around 3500 kDa when the radiation dose increased to 100 and 10 kGy for the xanthan irradiated in solid and solution, respectively. As the dose further increased, the M_v reductions of xanthan become slower.

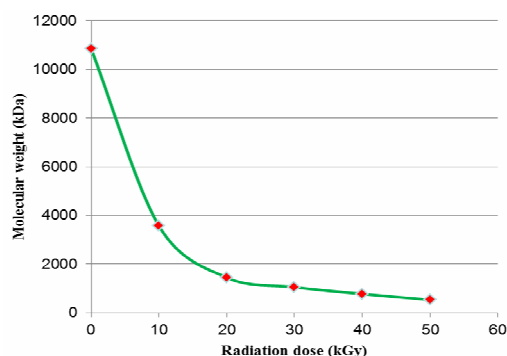


Figure 2. Viscosity average molecular weight of the xanthan irradiated in a solution as the function of radiation dose

Similar to other polysaccharides, the radiation degradation yield of xanthan, which irradiated in the solution, was higher than that in the solid state. Thus, gamma irradiation can be applied as effective way for preparation of low M_v xanthan.

3.2. Effects of xanthan and irradiated xanthan on the growth of seedlings

Table 1. The effects of the foliar fertilizers containing xanthan on the growth of maize seedlings

Sample	Plant height (cm)	Root length (cm)	Fresh biomass (g)
Control	38.3 ± 0.21	7.6 ± 0.32	76.4 ± 0.36
XT0-50	39.7 ± 0.38	8.1 ± 0.33	85.3 ± 0.27
XT0-100	40.3 ± 0.22	8.2 ± 0.25	86.2 ± 0.23
XT50-50	44.6 ± 0.28	8.7 ± 0.36	100.6 ± 0.34
XT50-100	44.1 ± 0.23	8.6 ± 0.34	99.4 ± 0.48
XT100-50	44.2 ± 0.29	8.7 ± 0.28	99.5 ± 0.24
XT100-100	44.9 ± 0.24	8.7 ± 0.37	100.4 ± 0.31



Figure 3. Effects of foliar fertilizer supplemented with 50 ppm of xanthan irradiated at 50 kGy (CM-1), 100 kGy (CM-2), and without xanthan as control (DC) on the growth of maize

Study on the adhesion properties of xanthan and its effects on the development of plant, the xanthan samples that irradiated at 0, 50 and 100 kGy (XT0, XT50 and XT 100) were added to Niphoska foliar fertilizer into the solution with xanthan concentration of 50 and 100 ppm. After fertilization and development during 4 weeks, the seedlings were collected and their plant height, length root and fresh biomass were calculated and presented in Table 1 and 2. The changes in plant morphology also observed in Fig 3 and 4.

Table 2. The effects of the foliar fertilizers containing xanthan on the growth of soybean seedlings

Sample	Plant height (cm)	Root length (cm)	Fresh biomass (g)
Control	18.4 ± 0.56	4.8 ± 0.31	30.2 ±
XT0-50	19.3 ± 0.48	5.1 ± 0.29	33.9 ± 0.37
XT0-100	19.6 ± 0.38	5.1 ± 0.25	34.2 ± 0.52
XT50-50	21.3 ± 0.49	5.4 ± 0.33	36.9 ± 0.43
XT50-100	21.8 ± 0.54	5.3 ± 0.35	37.4 ± 0.36
XT100-50	21.1 ± 0.35	5.3 ± 0.39	36.5 ± 0.48
XT100-100	21.6 ± 0.43	5.4 ± 0.37	36.6 ± 0.38



Figure 4 Effects of foliar fertilizer supplemented with 50 ppm of xanthan irradiated at 50 kGy (CM-1), 100 kGy (CM-2), and without xanthan as control (DC) on the growth of soybean

It is obvious that xanthan has significantly improved the growth of plants, and the growth rate of the seedlings sprayed with the irradiated xanthan higher than that with initial xanthan. Fresh biomass of maize and soybean fertilized with the irradiated xanthan were about 30 and 20% higher than that cultivated with foliar fertilizer only, whereas their plant height and root length also increased more than 10%.

However, there were no significant differences between the plants that were sprayed with foliar fertilizers containing the xanthan irradiated at 50 and 100 kGy. Therefore, the irradiated xanthan can be applied as good bio-adhesive for the foliar fertilizer.

4. CONCLUSION

The relative viscosity of xanthan was quickly reduced by gamma irradiation in both the dried state and the solution, whereas the decomposition of xanthan by gamma irradiation in the solution was much faster than in the solid state. Low Mv xanthan products are produced by radiation degradation at a rather small radiation dose from solution.

The effects of xanthan and the irradiated xanthan on the plant's growth were determined with maize and soybean seedlings that cultivated with Niphoska foliar fertilizers containing xanthan at concentration of 50 and 100 ppm. The results revealed that plant height, root length and fresh biomass of maize and soybean seedlings fertilized with xanthan and irradiated xanthan have significantly increased. In fact, the growth of the plant, which fertilized with the irradiated xanthan, seems not to be depended on the radiation dose. It may due to the irradiated xanthan acted as bio-adhesive for the foliar fertilizer only, but not affected on the plant growth like other low Mw polysaccharides that can act as plant promotor.

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