11. Utilization of Polysaccharides by Radiation Processing

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Radiation treatment has been applied for improvement or pasteurization of agro-resources to recycle the resources and to reduce the pollution of environment.

By using the radiation effect for pasteurization, upgrading of cellulosic wastes of oil palm to animal feeds and mushroom has been studied under the bilateral research cooperation between JAERI and MINT (Malaysian Institute for Nuclear Technology Research). The necessary dose for pasteurization of oil palm empty fruit bunch (EFB), which is a main cellulosic by-product of palm oil industry, was determined as 10 kGy. After pasteurization, the EFB substrate was inoculated with *Pleurotus sajor-caju* and fermented for 1 month. The digestibility and nutritional value of fermented products were evaluated as ruminant feeds and the mushroom can be produced as by-product.

For the improvement of resources, radiation effects on polysaccharides such as chitosan, sodium alginate, carrageenan, cellulose, pectin have been investigated to induce the biological activities. These carbohydrates were easily degraded by irradiation and induced various kinds of biological activities. The anti-bacterial activity and elicitor activity of chitosan were induced by irradiation. The induction of phytoalexins was also observed by irradiated pectin but the higher elicitor activity for pisatin was obtained by chitosan than pectin. For the plant growth promotion, alginate derived from brown marine algae, chitosan and ligno-cellulosic extracts show a strong activity. Carrageenan derived from red marine algae can promote growth of rice and the highest effect was obtained with kappa carrageenan irradiated at 100 kGy. Furthermore, some radiation degraded polysaccharides suppressed the damage of environmental stress on plants.

Keywords: Radiation, Pasteurization, Degradation, Polysaccharides, Plant growth

1. Introduction

Environmental pollution problems such as the green-house effect by increase of CO_2, acid rain caused by flue gases, and contamination of chemicals and pesticides in foods and water, have become serious all over the world with the rapid development of industry and agriculture. To solve some of these problems, radiation treatment has been applied for the removal of the contaminants from flue gases, decontamination of pathogenic microorganisms in various foods, medical supplies, sewage sludge, solid and liquid wastes from industrial plants. By the radiation treatment, the use of chemicals, pesticides, fumigants of EO, EDB, MB, etc., which are biohazard in the environment, can be decreased effectively.

Radiation treatment has the potential such as the pasteurization or sterilization of contaminated microorganisms and the improvement of the quality of materials by degradation, polymerization and grafting. This paper describes two topics on utilization of polysaccharides by radiation pasteurization and improvement. In the field of radiation pasteurization, upgrading of cellulosic agro-wastes has been studied to produce animal feeds and mushroom. For the improvement of quality, the utilization of radiation degraded polysaccharides has been studied to induce the biological activities for plant growth.

2. Upgrading of cellulosic wastes by radiation pasteurization

2.1. Upgrading of oil palm wastes by radiation pasteurization and fermentation

Empty fruit bunch (EFB) and palm press fiber (PPF) are major cellulosic solid wastes of the palm oil industry. The current availability of EFB and PPF are estimated to be 2.09 and 2.17 million tones (dry weight basis) respectively. These by-products are mainly discarded or under-utilized. EFB is normally incinerated to produce bunch ash, which is used as potash fertilizer or distributed in the field as mulch, while PPF is extensively used as fuel for the production of steam in the mills. However, burning and incineration processes emit considerable amount of smokes and pollutants thus affecting surrounding areas.

Recently, it has been realized the needs to utilize these by-products effectively to improve the economic situation of the oil palm industry as well as to reduce pollution problems. Research on the conversion of EFB and PPF into useful end-products has been reported. Both EFB and PPF were shown to have considerable potential as animal.

Gamma irradiation is presently being utilized for sterilization of medical products and preservation of foods in bulks by virtue of its high penetration ability. In relation to the similar application, the upgrading of oil palm wastes (mainly EFB) to animal feeds by radiation and fermentation treatment has been investigated under bilateral cooperation research program between MINT and JAERI [1].

2.2. Animal feeds from oil palm wastes

Animal feeds and mushrooms can be produced from oil palm cellulosic wastes by radiation and fermentation treatment. The process is as follows: decontamination of microorganisms in fermentation media of EFB by radiation, inoculation of useful fungi, and subsequently production of proteins and edible mushrooms (Fig. 1). The

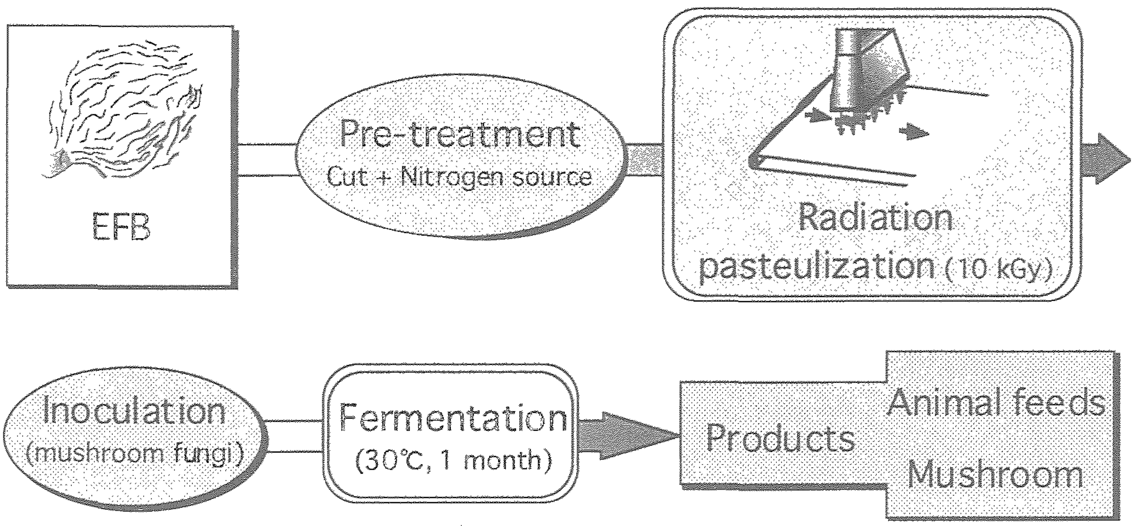
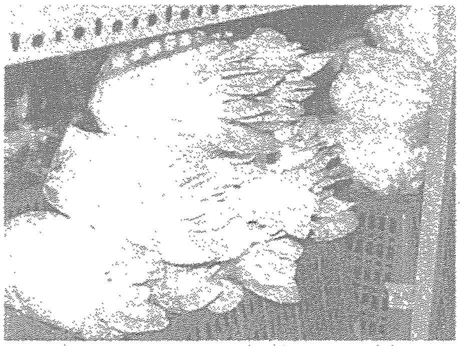


Fig. 1. Process for upgrading of oil palm wastes by radiation and fermentation treatment

necessary dose for pasteurization of EFB was determined as 10 kGy. After pasteurization, the EFB substrate was inoculated with useful fungi and fermented for 1 month. Among many fungi used for the digestion of EFB, *Coprinus cinereus* and *Pleurotus sajor-caju* were the most suitable microorganisms for the fermentation of EFB. The digestibility and nutritional value of fermented products were evaluated as ruminant feeds. The protein content increased to 13% and the crude fiber content decreased to 20%, and high yield of edible mushroom was obtained during fermentation using *P. sajor-caju* (Fig. 2). The digestibility and nutritional value of fermented products were evaluated as ruminant feeds and the lignin content was decreased effectively. It is, therefore, considered that EFB is a good substrate for mushroom and animal feeds production, and radiation and fermentation treatment is effective to utilize the cellulosic wastes as well as to reduce pollution problems.

The work on utilization of agro-waste was proposed for the UNDP/RCA/IAEA Project and accepted to start from February 1999. In the Program, more than ten member states have being investigated using various cellulosic wastes not only oil palm fiber but also sugarcane bagasse, rice straw and others.

Mushroom production



Fermented products

Composition	Before fermentation (mg/g)	Fermented products (mg/g)
Cellulose	467	338
Hemicellulose	185	103
Lignin	175	114
Crude protein	26	106

Improvement of quality for animal feeds
(1) Digestibility : Degradation of cellulose (decrease in lignin content)
(2) Nutritional value : Increase in protein contents

Fig. 2. Products from EFB by radiation and fermentation treatment

3. Improvement of polysaccharides by radiation degradation

It is reported that the oligosaccharides from higher plant cell wall involved in capable of signal transduction, defense responses against pathogens and synthesis of phytoalexins [2]. Low molecular weight carbohydrates and oligosaccharides are usually prepared by enzymatic degradation but the radiation is one of the potent procedures for fragmentation of polysaccharides. Radiation generates various types of degraded fragments by random scission and induces various kinds of biological activities for plant cultivation. In this study, various polysaccharides such as chitosan, sodium alginate, carrageenan, cellulose and pectin were used and analyzed the biological activities.

3.1. Induction of phytoalexin by radiation-degraded polysaccharides

Radiation causes the cleavage of glycosidic link of polysaccharides, producing lower fractions [3-5]. Figure 3 shows the irradiation effect on molecular weight of alginate in liquid state (4% solution) and in solid state. Similar degradation was observed in case of pectin and chitosan by irradiation. Using these degraded pectin and chitosan, the induction of elicitor activity was examined [6]. Pectic fragments prepared by irradiation and oligogalacturonan obtained by enzyme digestion (endo-PG) of pectin induced glyceollins (a kind of phytoalexin). The pectic fragments obtained by irradiation with 1000 kGy were the most effective for induction of glyceollins and induced almost the same amount of glyceollins induced by endo-PG. Pisatin, a phytoalexin induced in pea, was also effectively induced by irradiated pectin and

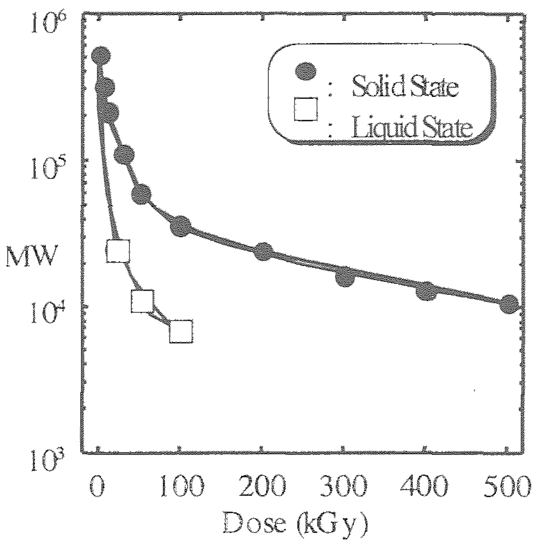


Fig. 3 Change in molecular weight of alginate by irradiation

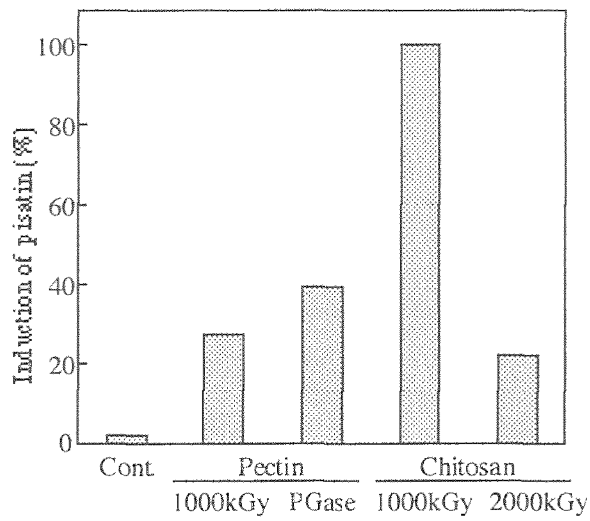


Fig. 4 Induction of pisatin in pea by irradiated pectin and chitosan

chitosan (Fig. 4). Induction of pisatin by pectic fragments prepared by irradiation was lower than that of pectin-PGase. Chitosan irradiated at 1000 kGy in solid state induced much higher activity than the pectic fragments but decreased at 2000 kGy. These results show that 1000 kGy is the optimum dose to obtain the effective fragments for induction of phytoalexins and a dose of more than 2000 kGy is too high to keep effective fragments.

3.2. Effect of radiation-degraded polysaccharides on plant growth

Growth-promotion of plant was tested under hydroponics cultivation condition. For rice, degraded alginate in 4% alginate solution irradiated at 100 kGy (MW ca. 7000) or from powder irradiated at 500 kGy impact remarkable effect on growth promotion. The suitable range of degraded alginate concentration was 20- 50 ppm. The results suggest that foliar spraying degraded alginate at certain concentration causes increasing in biochemical and physiological functions of plant that lead to increase in dry matter. Preliminary results on field test of foliar spraying of degraded alginate on tea, carrot and cabbage with concentration of 20 to 100 ppm, led the increase of productivity of ca. 15 to 40%. Similar effects were also observed by chitosan, lignocellulose extracts and carrageenan. Kappa and iota carrageenan derived from red marine algae can promote growth of rice (Fig. 5) and the highest effect was obtained with iota irradiated at 100 kGy (Fig. 6).

Fig. 5 Enhancement of rice growth by irradiated carrageenan

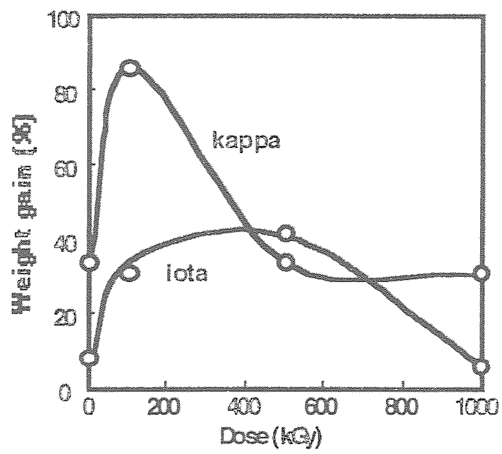


Fig. 6 Effect of irradiation dose on carrageenan for rice growth

3.3. Suppression of heavy metals stress on plants by radiation degraded polysaccharides

Heavy metals such as vanadium (V) and zinc (Zn) show the strong stress on soybean, rice, wheat and barley seedlings, whose roots were clearly injured at 5 ppm V (in VCl_3) in solution cultures. These damages were relatively reduced by application of radiation degraded chitosan. The recovery of growth and reduction of V levels in seedlings were obtained by the treatments with 100 and 200 ppm chitosan irradiated at 100 kGy in 1% solution (Table 1). Thus, the chitosan irradiated at suitable doses could be suggested as heavy metal eliminators in crop production.

Table 1. Effect of V and irradiated chitosan on plant growth

Treatment		Dry weight of seedlings (mg/10 plants)			
		wheat		rice	
V(ppm) +	Chitosan(ppm)	Biomass	%	Biomass	%
0	0	385 ± 42	100	190 ± 17	100
0	100	544 ± 47	141	206 ± 16	108
0	200	540 ± 39	140	236 ± 30	124
10	0	229 ± 37	59	143 ± 12	75
10	100	350 ± 35	91	214 ± 18	113
10	200	392 ± 39	102	210 ± 18	111

Seedlings of plants grown for 9 days under V stress with chitosan irradiated at 100 kGy were measured.

The results suggest that the fractions of polysaccharides act on plants as phytohormone-like compounds for growth and suppression of environmental stress such as heavy metals and salts.

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