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Effects of Ionizing Radiation on Development of Wound Periderm, Solanine Content, and the Formation of Carbonyl Compounds in Potato Tubers

by

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放射線 照射가 감자 塊莖의 治癒組織形成, Solanine 含量 및 Carbonyl 化合物에 미치는 影響

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Abstract

Effect of various dosages of gamma ray ranging from 0 to 16 krad on wound periderm formation was investigated with aging potato tuber slices (1cm×2mm) under aseptic condition. Cell division was gradually inhibited with increasing dosage, and completely prevented with 16 krad treatment.

Solanine content was not significantly different due to dosages. Gas chromatographic separation of 2,4-dinitrophenylhydrazone precipitate from radiation-induced carbonyl compounds in potato tubers showed that formaldehyde and acetone tended to be increased only with high dosages.

Introduction

The fact that ionizing radiation is very effective in preventing sprout growth of potato tubers and has no adverse effects on their nutritive value and cooking quality has been reported in a previous paper.(1) However, for commercial acceptance of irradiated potatoes, it is extremely important to investigate whether subsidiary harmful-effects are accompanied by sprout prevention of potato tubers.

It has been generally recognized that irradiation inhibits wound periderm formation in cut potato tubers as well as cell division leading to potato sprout inhibition. Susceptibility to storage rot might be seriously increased in the event that unhealed cuts and bruises are exposed to ionizing radiation.(2) Accordingly studies were undertaken to determine the effects of various dosages of gamma ray on wound periderm formation of potato tuber slices.

Solanine, a steroidal alkaloid, present in potatoes is known to be potentially toxic, and thus it is of profound significance to examine whether irradiation influences solanine content of potato tubers.

Irradiation has already received clearance for use as potato sprout inhibitor in various countries.(3) However, a recent report(4) suggests that the formation of potential mutagenic or cytotoxic agents might result from chemical transformations in food components by irradiation. It is probable that irradiation of succulent food, such as potatoes, might increase the production of a variety of new substances because of free radical reaction.[5] The radiation-induced formation of keto- and aldehyde-compounds in carbohydrates was studied by Löfroth and Kim.[6] Since an accumulation of carbonyl compounds in irradiated potatoes would be harmful for human consumption, the pattern of carbonyl compound formation by various dosages of gamma ray was investigated as a part of wholesomeness study.

Materials and Methods

All experiments were accomplished with "Irish Cobbler" potatoes stored at 5°C. Studies on wound periderm formation were conducted with tuber slices aged 1 week at 25°C. Slices 2mm thick and 1 cm in diameter were cut off from central tuber tissue (mainly pith and storage parenchyma of the inner phloem) employing slicer designed for this specific prupose.[7] Aseptic technique was followed in cutting and aging slices.

For microscopic examination of phellogen formation, pieces of tissue approximately 5×5 mm were cut out from aged tuber slices. Cut tissues were fixed in formalin-acetic acid solution for a week, dehydrated with a series of tertiary butyl alcohol solutions, and embedded in paraffin. Sections were cut at 5 μ with rotary microtome, and stained with iron-alum haematoxylin.[8]

Determination of solanine (including solanidine) content was based on procedures described by Liljemark and Widoff.[9] The absorbance of the final preparation was read at 570 nm by Beckman DU-2 Spectrophotometer. A 2×5 factorial arrangement of treatments was established in this study.

For gas chromatographic separation of carbonyl compounds, a weighed amount of potatoes was blended in 0.2 N HCl with waring blendor for 2 minutes, and adjusted with 2 N HCl to pH 1.0. The homogenate was filtered through four layers of cheese cloth and successively Toyo No. 5 C filter papers. The resulting extract was combined with an equal amount of 0.8% (v/v) 2,4-dinitrophenylhydrazine solution, prepared by dissolving purified 2,4-dinitrophenylhydrazine in 1 : 1 2 N aqueous HCl-ethanol.

The possible reaction between 2,4-dinitrophenylhydrazine and unchanged reducing sugar was eliminated by carrying out the precipitation at 4°C. After 2 hour standing, the yellow precipitate of 2,4-dinitrophenylhydrazone was filtered off under aspiration through 3 G4 glass filter, and washed with 2 N HCl and triple distilled water three times respectively. Filtered precipitate was vacuum dried and weighed accurately. The precipitate was dissolved in chloroform at the rate of 20% w/v. Complete dissolution was accomplished in the glass cap stoppered micro vial by incubating it for 5 minutes in a shaker bath at 120 oscillations per minute. The solution was immediately filtered through Toyo No. 7 filter paper.

Prepared sample was analyzed in a Varian Aerograph Series 2100 gas chromatograph fitted with a flame ionization detector. The column used was 5 ft × 1/16 inch stainless steel tube packed with 5% SE-30 on 70/80 mesh Chromosorb W, DMCS treated. The column was operated at 185°C and detector and injection port temperatures were 240°C and 250°C respectively. The flow rate of the carrier gas (nitrogen) was 25 ml/minute on the analytical column.

Potatoes for solanine analysis and tuber slices were irradiated at a dose rate of 1,350~1,400 rad/hr respectively on March 28 and May 2, 1972, at Atomic Energy Research Institute as described in the previous paper.[1] Potatoes for carbonyl compound determination were irradiated at a dose rate of 194 rad/sec by newly introduced Co^{60} BNL shipboard irradiator (20,000 Ci gamma ray). All analyses were 2 or 3 times replicated. Potato tubers were stored at room temperature after irradiation.

Results and Discussion

The effects of gamma ray treatment on wound periderm formation are illustrated by the photographs of sectioned slice tissues from the control and from the 16 krad treated samples (Fig. 1). A number of characteristic wound periderm layers developed in the unirradiated slices (Fig. 1A). It was observed that such low dosage as 2 krad resulted in decidely reduced cell divisions, and that still greater suppression occurred at 4 and 8 krad respectively. Cell division was entirely eliminated by 16 krad treatment (Fig. 1 B), which coincides with the dosage resulting in complete prevention of sprout growth. Data on the number of newly divided cells at various dosages of gamma ray are presented in a succeeding paper.

According to previous reports,[10, 11] wound periderm formation and suberization appear to be inhibited by irradiation at maximum dosages necessary for commercial control of sprouting. However, the present result shows that cell divisions are suppressed by much lower dosages of gamma ray than those required to prevent sprout growth of potato tubers. The practical consequence of this effect is that serious decay might result from irradiated potato tubers unless sufficient curing period is allowed before irradiating freshly harvested potatoes, and mechanical damage during irradiation be avoided.

In the normal potato tubers, solanine content usually ranges from less than 10 mg per 100 g to more than 30 mg per 100 g depending on the varieties. It is known that potato tubers containing more than 20 mg of solanine per 100 g are not suitable for food.[12]

As shown in Table 1, "Irish Cobbler" potatoes contained 4~6 mg solanine, and it appears that the irradiation did not affect the total content of solanine in potato tubers under the present experimental condition. Total solanine content did not significantly differ between immediately after and three weeks after irradiation at the various dosages of gamma ray treatments. Irradiated tubers had a slightly higher proportion of solanine than the unirradiated controls, even though there were no statistically significant differences among various dosages of gamma ray treatments.

Since sprout growth of potato tubers is probably accompanied by a reduced solanine content in the outer parts of potato tuber,[13] it might be also possible that slightly lower content of solanine in unirradiated tubers was attributable to prevalent sprout growth and consequent decrease of solanine content in the unirradiated tubers after the 3 week storage at room temperature.

Whatever the relationship between gamma irradiation and total solanine content, it is clear that irradiated tubers contained far lower solanine than the toxic level for human consumption.

An early worker[14] indicated that the solanine content was increased in a strongly greened potato only 8~10 mg per 100 g by irradiating under sunlight. According to Sutton et al.,[13] irradiation of potato seed tubers resulted in a definite but insignificant increase of total solanine present in potatoes grown from the treated seed.

Studies on the radiation-induced formation of carbonyl compounds were confined to low molecular weight components. Fig. 2 shows gas chromatogram of 2, 4-dinitrophenylhydrazone precipitate from radiation-induced carbonyl compounds in potato tubers. Peaks were respectively identified as formaldehyde, acetaldehyde and acetone.

Formaldehyde and acetone were chosen for quantitative estimation of carbonyl compounds produced in potato tubers treated with various dosages of gamma ray. Immediately after irradiation, no great differences were found in formaldehyde yield among 0, 12, 60, and 300 krad treated tubers. However, the formaldehyde yield was sharply increased in 1, 500 krad treated tubers.

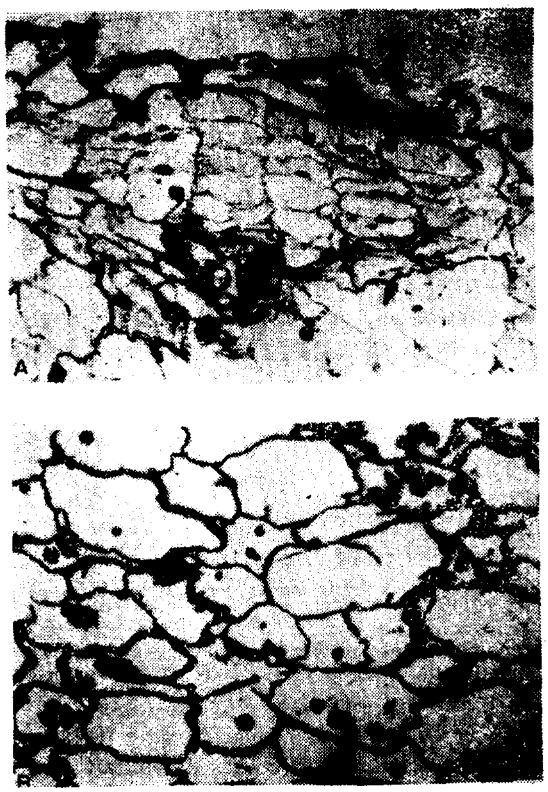

Fig 1. Cross sections of potato tuber slices aged 1 week. (×220) A. unirradiated tissue showing wound periderm formation. B. Tissue treated with 16 krad gamma ray, showing no wound periderm development

The yield of formaldehyde was approximately 10 to 20 times greater in 1,500 krad treatment compared with other treatments. The acetone yield was not greatly different among various dosages of gamma ray treatments, even though 1,500 krad treated tubers tended to contain somewhat increased amount of acetone. Formaldehyde and acetone yield was also estimated at 1, 2, and 4 weeks after irradiation. No consistent effect was shown due to dosages in these stored tubers.

As a result of investigating effect of gamma irradiation on volatile compounds of cooked potatoes, Tazima et al.[15] reported that acetaldehyde and several other aldehyde compounds were increased in 100 krad treated tubers, while their result showed that the acetone yield was not changed. However, because of extremely serious tuber to tuber variation and the complexity of the living system,[16] no definite conclusions can be drawn from the present study concerning the pattern of carbonyl compounds production in potato tubers treated with various dosages of gamma ray.

Table 1. Effect of various dosages of gamma ray on solanine centent of potato tubers 0 and 3 weeks after irradiation[x,y]

Treatments	Solanine content (mg %)
Time	
Immediately after irradiation	5.1 a
Three weeks after irradiation	4.8 a
Dosage (krad)	
0	4.3 a
2	5.3 a
4	5.0 a
8	4.7 a
16	5.4 a
Interaction	n.s.

x: Any two means followed by a common letter are not significantly different at 5% level by the honestly significant difference (hsd) of Tukey's procedure.

y: This experiment was designed as 2 (time)×5 (dosage) factorial arrangement. Accordingly main effect of one factor reveals mean value of all levels of other.

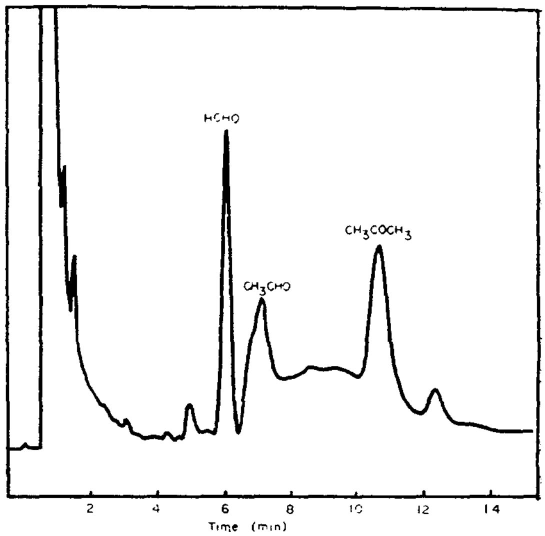

Fig 2. Gas chromatogram of 2,4-dinitrophenylhydrazone precipitate from radiation-induced carbonyl compounds in potato tubers

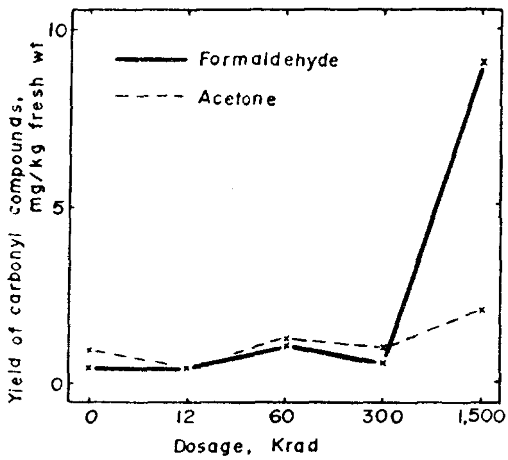

Fig 3. Ettect of various dosages of gamma ray on carbonyl compounds production of potato tubers

요 약

여러가지 線量의 放射線照射가 감자 薄片(1 cm×2 mm)의 治癒組織 형성에 미치는 효과를 무균 상태하에서 調査하였다. 세포분열은 線量이 증가함에 따라 점차 억제

되었고 16krad 처리에서는 완전히 억제되었다.

Solanine 함량은 線量에 따라 有意的인 차이를 나타내지 않았다. 放射線照射에 의하여 감자 塊莖 내에 誘起된 carbonyl 화합물로 부터 생성된 2,4-dinitrophenylhydrazone 침전물을 gas chromatograph로 분리한 결과 formaldehyde 및 acetone은 高線量에서만 증가하는 경향을 보였다.

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