Applicability of Impedance Measuring Method to the Detection of Irradiation Treatment of Potatoes

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The incubation condition of potato tubers prior to impedance measurement greatly influenced the reliability of detection of irradiated potatoes; the impedance ratio at 5kHz to 50kHz (Z_{5k}/Z_{50k}) determined at 22°C at an apical region of tuber which was pre-incubated at 22°C for 3 days or longer resulted in the best detection of radiation treatment of potatoes. The impedance ratio was dependent upon dose applied to potato tubers. Potatoes irradiated at 100 Gy could be distinguished from unirradiated potatoes for 10 cultivars of potatoes. The impedance ratio of potatoes irradiated at the same dose was little influenced by the planting locality if the cultivar was the same, although the ratio varied with potato cultivars. These results indicate that irradiated potatoes can be detected if the potato cultivar is known. Potatoes 'Danshaku' commercially irradiated at the Shihiro Potato Irradiation Center could be differentiated from unirradiated 'Danshaku' at different planting localities; the impedance ratio was lower than 2.75 for the unirradiated potatoes and higher than 2.75 for the irradiated ones.

Potatoes are legally allowed in Japan to be irradiated with Co-60 gamma-rays on a commercial basis in order to inhibit sprouting. Every year around 15,000 t of potatoes are irradiated at doses of 60 to 150 Gy. Although the wholesomeness of irradiated potatoes has already been confirmed, some consumers are against irradiation and request the responsible authorities to develop a reliable method to differentiate irradiated potatoes from unirradiated ones. A technique to detect irradiated potatoes should be dependent upon the radiation dose but not on other conditions for growth, harvest and storage. Such a technique is also useful to avoid re-irradiation treatment and to control irradiation process of potatoes and distribution of irradiated products.

A reliable technique to detect irradiated potatoes has not so far been established, although several methods have been proposed. Most of these methods deal with enzyme activities or with the amount of potato components such as carbohydrates, amino acids, vitamins and chlorogenic acid, all of which change during storage and are influenced by the storage and growth conditions.

The technique of measuring the electrical conductivity or impedance of potatoes has been reported to be promising for the identification of irradiated potatoes. In the previous study, it was found that the impedance ratio at 5kHz to 50kHz (Z_{5k}/Z_{50k}) determined at 22°C at an apical region of potato tuber resulted in the best detection of irradiated potatoes. However, the impedance ratio fluctuated to a great extent, which did not enable a clear discrimination of irradiated potatoes from unirradiated ones. The impedance change of potato tubers would detect the physiological changes of membranes, and the physiological condition would be influenced by storage conditions of potato tubers. It was expected that the storage condition prior to impedance measurement would influence the impedance of
potatoes.
In the present study we examined the influence of incubation condition prior to impedance measurement on the fluctuation of the impedance ratio \(Z_{5k}/Z_{50k}\) of potato tubers in order to establish the best detection method of irradiated potatoes. The applicability of the impedance measuring method to various cultivars of potatoes was investigated as well.

**Materials and Methods**

**Potato**

The following cultivars of potatoes were provided by Hokkaido National Agricultural Experiment Station in Eniwa, Hokkaido; May Queen, Kitaakari, Ezoakari, Waseshiro, Toyoshiro, Hockkaikogane, Norin-No.1 and Benimarut. Potatoes of cv. Danshaku (harvested in Shihoro, Tokoro, Kunneppu and Makkari) and cv. Dejima (harvested in Unzen, Goto and Kazusa) and the potatoes 'Danshaku' irradiated at Shihoro Potato Irradiation Center were purchased at a local market in Tsukuba. Twenty potatoes from one lot of sample were subjected to impedance measurements, unless otherwise stated.

**Irradiation**

Potatoes were irradiated with a Gamma Cell 220 (AECL, Co-60, 5.4 kGy/h). The accuracy of the dose rate was within 15%. Both irradiated and unirradiated potatoes were stored at 5°C in a dark room, unless otherwise stated.

**Impedance measurement**

Prior to the electrical measurement the potatoes were incubated for 3 days at 22°C, unless otherwise stated, and the impedance was measured at the temperature with the aid of a stainless-steel two electrode system; 1 mm diameter, 10 mm long and 10 mm distant\(^{13}\). An apical region of potato tuber was punctured with the steel electrodes which were connected to a Digital Spectral Analyzer TR 9403 (Advantest LTD.). The impedance at 5kHz and 50kHz were measured to determine the impedance ratio at 5 kHz to 50 kHz \((Z_{5k}/Z_{50k})\).

**Determination of the effect of pre-incubation at 22°C on the impedance ratio**

Potatoes of cv. Danshaku (harvested in Shihoro) and cv. Dejima (harvested in Goto) irradiated at 0 or 100 Gy were stored for 1 month at 5°C, and then the potatoes were incubated for 1, 3 or 7 days at 22°C, followed by the impedance measurement.

![Fig. 1 Impedance ratios of potatoes of cv. Danshaku which were incubated for different period at 22°C prior to the impedance measurement](image-url)
Determination of the effect of storage at 5°C on the impedance ratio

Potatoes of cv. Danshaku (harvested in Shihoro) were irradiated at 0 or 100 Gy and then stored at 27°C for 1 month. Some of the potatoes were shifted to a storage room at 5°C, followed by storage for 1 week at 5°C. The rest of the potatoes were kept in the storage room at 27°C. The impedance ratio of all of the potatoes were determined at 22°C following the pre-incubation for 3 days at 22°C.

Results and Discussion

Effect of pre-incubation at 22°C on the impedance ratio

The impedances of unirradiated potatoes of cv. Danshaku at 5 kHz were in a range of 2.30 and 3.20, while those of irradiated potatoes (100 Gy) were in a range of 2.95 and 4.10. The impedances at 50 kHz were in a range of 1.05 and 1.50, irrespective of irradiation treatment. Most of the impedance ratios \( \frac{Z_{5k}}{Z_{50k}} \) of the unirradiated potatoes of cv. Danshaku were lower than 2.75 and those of irradiated potatoes (100 Gy) were higher than 2.75 (Fig. 1). The difference in the impedance ratio

Fig. 2 Impedance ratios of potatoes of cv. Dejima which were incubated for different period at 22°C prior to the impedance measurement

\( \square \); 0 Gy, \( \blacksquare \); 100 Gy

Fig. 3 The effect of storage at 5°C prior to the impedance measurement on the impedance ratio of potatoes which were stored at 27°C

\( \square \); 0 Gy, \( \blacksquare \); 100 Gy
between unirradiated potatoes and irradiated ones became larger with the increase in the incubation period at 22°C prior to the impedance measurement.

The impedances of unirradiated potatoes of cv. Dejima at 5 kHz were in a range of 2.60 and 4.25, while those of irradiated potatoes (100 Gy) were in a range of 3.90 and 5.90. The impedances at 50 kHz were in a range of 0.85 and 1.20, irrespective of irradiation treatment. The influence of pre-incubation at 22°C on the impedance ratio of ‘Dejima’ was similar to that of ‘Danshaku’; the potatoes of cv. Dejima incubated for 1 day at 22°C showed less distinct difference in the impedance ratio between unirradiated and irradiated tubers, as compared with those incubated for 3 or 7 days at 22°C (Fig. 2).

These results indicate that potatoes should be incubated at 22°C for 3 days or longer before the impedance measurement in order to clearly differentiate irradiated potatoes from unirradiated ones.

Effect of storage at 5°C on the impedance ratio

The impedance ratios of the unirradiated potatoes which were not stored at 5°C fluctuated to a greater degree than those of the potatoes which were stored at 5°C (Fig. 3). The results indicate that the potatoes which have been stored at a relatively high temperature should be once stored at a low temperature before the impedance measurement.

Dose dependency of the impedance ratio

The impedance ratios (Z5k/Z50k) of the potatoes ‘Danshaku’ which were determined after storage for 1 month at 5°C increased with the dose (Fig. 4).

![Graph](image1)

**Fig. 4** Impedance ratios of potatoes which were irradiated at different doses

- [ ]; 0 Gy, [ ]; 60 Gy, [ ]; 100 Gy, [ ]; 150 Gy

![Graph](image2)

**Fig. 5** Impedance ratios of potatoes of cv. Danshaku at different planting localities

- [ ]; 0 Gy, [ ]; 100 Gy
Impedance ratios of potatoes at different planting localities

The impedance ratios \((Z_{5k}/Z_{50k})\) of unirradiated and irradiated (100 Gy) potatoes of cv. Danshaku and Dejima at different planting localities are shown in Fig. 5 and 6. Most of the impedance ratios of the unirradiated potatoes of cv. Danshaku were lower than 2.75 and most of those of the irradiated ones were higher than 2.75, irrespective of planting locality (Fig. 5). Most of the impedance ratios of the unirradiated potatoes of cv. Dejima were lower than 3.25 and most of those of the irradiated ones were higher than 3.50, irrespective of planting locality (Fig. 6). The results shown in Fig. 4, 5 and 6 suggest that the irradiated potatoes can be detected with the impedance ratio, without any information about planting locality.

Impedance ratios of the potatoes commercially irradiated at Shihoro Potato Irradiation Center

Most of the impedance ratios of the potatoes commercially irradiated at Shihoro Potato Irradiation Center were in a range of 2.75 and 3.25, irrespective of irradiation date (1991. 11. 28. and 1992. 2. 3.) (Fig. 7). There was a significant difference in the impedance ratio between the unirradiated potatoes and the commercially irradiated ones at a level of 5%. The results shown in Fig. 4, 5 and 7 suggest that the commercially irradiated potatoes can be discriminated from unirradiated potatoes of cv. Danshaku with the parameter of \(Z_{5k}/Z_{50k}\); most of the parameters were lower than 2.75 for unirradiated potatoes and higher than 2.75 for the commercially irradiated ones.

![Graphs of impedance ratios for Unzen, Kazusa, and Goto](image-url)

Fig. 6 Impedance ratios of potatoes of cv. Dejima at different planting localities.

- [Unzen](image-url)
- [Kazusa](image-url)
- [Goto](image-url)

Fig. 7 Impedance ratios of the potatoes commercially irradiated at Shihoro Potato Irradiation Center.

- [Unirradiated](image-url)
- [Irradiated on Nov. 28, 1991](image-url)
- [Irradiated on Feb. 3, 1992](image-url)
Impedance ratios of various cultivars of potatoes

The impedance ratios, \( Z_{5k} / Z_{50k} \), of irradiated potatoes (100 Gy) were significantly different from those of unirradiated ones at a level of 1% for potato cultivars of Benimaru, Hokkai-kogane, May Queen, Toyoshiro, Ezoakari, Kitaakari, Norin-No.1 and Waseshiro (Fig. 8). Based on the results shown in Fig. 4-8, however, the impedance ratio of potatoes irradiated at the same dose varied with the potato cultivar, which suggests that the identification of irradiated potatoes is impossible without any information about potato cultivar. However, irradiated potatoes can be detected by the impedance measuring method if the potato cultivar is known, because the impedance ratio at 5 kHz to 50 kHz was not influenced by the planting locality.

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References


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