Impedance Measurement of Irradiated Potatoes

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The impedance ratio of a potato tuber at 50kHz to 5kHz (Z_{50k}/Z_{5k}) was dependent upon the irradiation dose, while it was independent of the locality where potatoes were grown. It remained constant during the storage after irradiation. The impedance ratio for unirradiated potatoes was almost the same irrespective of the potato variety. The possibilities of differentiation between unirradiated and irradiated potatoes and estimation of irradiation dose were discussed based on the results.

A reliable technique to identify irradiated potatoes has not been established so far, though several methods have been reported^{1)~12)}. Most of these dealt with the enzyme activities⁴⁾⁶⁾ or the components⁵⁾ of tubers. However, all these were easily influenced by their growth and storage conditions. The technique of measurement of impedance has been reported^{7)~12)} to be promising as a means of identification of irradiated potatoes. In the previous study¹²⁾, the impedance of potatoes of var. Danshaku was measured to establish the best conditions for the identification, and the best parameter was found to be a ratio of impedance at 50 kHz to at 5 kHz (Z_{50k}/Z_{5k}) at a temperature of 20°C. This parameter was dependent upon the irradiation dose and remained almost constant even for a long period of storage up to 6 months after irradiation, irrespective of the storage temperature.

In this study, potatoes of var. Danshaku which were grown in different localities and other varieties of potato were irradiated with a dose of 0 to 300 Gy and their impedances were measured at 20°C, in order to investigate the practicability of the impedance measure-

ment as a technique for the identification of irradiated potatoes.

1. Materials and Methods

(1) Potato samples

The following samples of potato were used in this study: Danshaku (grown in Shihoro, Hokkaido), Danshaku (Nakafurano, Hokkaido), Danshaku (Nakashibetsu, Hokkaido), Hakushaku (Nishikagura, Hokkaido), May-Queen (Memuro, Hokkaido) and Dejima (Nagasaki, Nagasaki-ken). All the potato samples were purchased from a local market in Tsukuba, Ibaraki-ken.

(2) Irradiation method

The potatoes were irradiated with a dose of 0 to 300 Gy using a Gamma Cell 220 (Canada AEC, Co-60, 2.80 kGy/hr. $\pm 15\%$). After irradiation, the potatoes were stored at 5°C in a dark room.

(3) Impedance measurements

Prior to the experiments, the temperature of the potatoes was maintained at 20°C, and the electrical measurements were carried out at that temperature using stainless steel electrodes and a Vector Impedance Meter 4800 A (Hewlett Packard LTD.) as reported previously¹²⁾. The results were shown with the ratio of impedance at 50 kHz to 5 kHz (Z_{50k}/Z_{5k}). The mean value and standard deviation were determined from 10 measurements using 10 samples from each lot.

2. Results and Discussion

(1) Impedance ratio of var. Danshaku

The impedance ratio determined with potatoes of var. Danshaku 1 week or 4 months after irradiation was dependent upon the irradiation dose but independent of the locality where the potatoes were grown (Table 1). The impedance ratio remained almost constant during the storage. These results indicated the possibility of the estimation of the irradiation dose by impedance measurement.

(2) Impedance ratio of other varieties

The impedance ratio determined 1 week after irradiation was dependent upon the irradiation dose for all the potato varieties tested (Table 2). The susceptibility, however, of this ratio to gamma-radiation was

Table 1 Impedance ratio of Danshaku grown in different localities

a) Shihoro

Dose (Gy)	Storage Period after Irradiation	
	1 week	4 months
0	0.393±0.019	0.393±0.024
70	0.333±0.016	0.338±0.026
150	0.299±0.018	0.309±0.020
300	0.268±0.023	0.266±0.017

b) Nakafurano

Dose (Gy)	Storage Period after Irradiation	
	1 week	4 months
0	0.377±0.007	0.379±0.015
70	0.317±0.013	0.333±0.011
150	0.298±0.012	0.293±0.009
300	0.265±0.015	0.268±0.010

c) Nakashibetsu

Dose (Gy)	Storage Period after Irradiation	
	1 week	4 months
0	0.400±0.021	0.384±0.022
70	0.319±0.027	0.325±0.019
150	0.292±0.009	0.302±0.021
300	0.259±0.016	0.263±0.025

Table 2 Impedance ratio of different varieties of potato

Dose (Gy)	Variety of Potato		
	Dejima	Hakushaku	May-Queen
0	0.392±0.020	0.373±0.019	0.380±0.017
20	0.280±0.010	0.332±0.020	0.302±0.018
150	0.248±0.016	0.311±0.015	0.262±0.024
300	0.224±0.014	0.299±0.020	0.241±0.020

different among the different varieties of potato. In contrast, the impedance ratio for unirradiated samples showed a constant value, irrespective of the potato variety (Table 1 and 2). In order to examine the possibility of differentiation between unirradiated and irradiated potatoes, the confi-

Table 3 Confidence limits of the mean value of the impedance ratios at a significance of 95%

Variety	0 Gy		70 Gy	
	Upper Limit	Lower Limit	Upper Limit	Lower Limit
Danshaku (Shihoro 1 week)	0.406	0.379	0.344	0.322
Danshaku (Shihoro 4 months)	0.410	0.376	0.357	0.310
Danshaku (Nakafurano 1 week)	0.378	0.376	0.326	0.308
Danshaku (Nakafurano 4 months)	0.390	0.368	0.341	0.325
Danshaku (Nakashibetsu 1 week)	0.415	0.385	0.338	0.300
Danshaku (Nakashibetsu 4 months)	0.400	0.368	0.339	0.311
Dejima	0.406	0.378	0.287	0.318
Hakushaku	0.387	0.359	0.346	0.318
May-Queen	0.392	0.368	0.314	0.289

dence limits of mean value (MV) of the impedance ratios at 95% significance were calculated for the potatoes irradiated at 0 or 70 Gy, using the following equation with the assumption that the impedance ratios distributed normally.

$$\bar{x} - t \cdot s / \sqrt{n} < MV < \bar{x} + t \cdot s / \sqrt{n}$$

where $\bar{x}$ = mean value of 10 measurements

$$t = t(9, 0.025) = 2.262$$

s = standard deviation of 10 measurements

$$n = 10$$

As shown in Table 3, almost all the lower confidence limits for unirradiated potatoes were higher than 0.360, while all the upper limits for the irradiated samples were lower than 0.360. These results indicated the possibility of differentiating between unirradiated and irradiated potatoes by means of impedance measurement with more than 10 potatoes with a probability of 95% or higher.

The probability for an impedance ratio to

Table 4 Probability for an impedance ratio to be heigher than 0.360 for unirradiated potatoes or lower than 0.360 for irradiated potatoes

Variety	Probability (%)	
	Unirradiated > 0.360	Irradiated (70 Gy) < 0.360
Danshaku (Shihoro 1 week)	95.8	95.4
Danshaku (Shihoro 4 months)	91.6	80.0
Danshaku (Nakafurano 1 week)	99.2	99.9
Danshaku (Nakafurano 4 months)	89.7	99.3
Danshaku (Nakashibetsu 1 week)	97.2	93.5
Danshaku (Nakashibetsu 4 months)	86.3	96.7
Dejima (1 week)	94.5	99.9
Hakushaku (1 week)	75.2	91.9
May-Queen (1 week)	87.9	99.9

be higher than 0.360 for unirradiated potatoes (P_U) or lower than 0.360 for irradiated potatoes (P_I) was calculated with the help of the following equations assuming that a mean value and a standard deviation of population were those observed.

$$P_U = \int_{0.360}^{\infty} \frac{1}{\sqrt{2\pi}\sigma} \exp \left\{ -\frac{(x-\mu)^2}{2\sigma^2} \right\} dx$$

$$P_I = \int_{-\infty}^{0.360} \frac{1}{\sqrt{2\pi}\sigma} \exp \left\{ -\frac{(x-\mu)^2}{2\sigma^2} \right\} dx$$

where x = impedance ratio

σ = standard deviation of population

μ = mean value of population

As shown in Table 4, the probabilities were different dependent upon the potato variety in the range between 75.2% and 99.9%. These results indicated the possibility of differentiating between unirradiated and irradiated potatoes with one impedance ratio with a probability of higher than 75%.

3. Conclusion

The impedance measurement could be a practical method to differentiate between

unirradiated and irradiated potatoes, even when the variety was unknown. A mean value of 10 measurements enabled the differentiation with a probability of 95% or higher, while the differentiation was possible with a probability of higher than 75% with only one impedance ratio. Furthermore approximate estimation of irradiation dose was possible provided the potato variety was known, because the impedance ratio for irradiated potatoes varied according to the variety. The ratio was stable during storage and was independent of the locality where the potatoes were grown.

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照射馬鈴薯のインピーダンス

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照射馬鈴薯の検知を行うために照射線量を表わすパラメータとして、50 kHz と 5 kHz におけるインピーダンスの比 (Z_{50k}/Z_{5k}) を用いた。このパラメータは、同一品種なら、馬鈴薯の栽培地の影響は受けず、線量にのみ依存しており、長期間貯蔵後も一定であった。非照射馬鈴薯に対するこのパラメータは、品種間の差はなく一定であった。これらの結果に基づいて、非照射馬鈴薯と照射馬鈴薯の識別および照射線量の推定の可能性について論じた。