Improved Storage Life of Fruits and Vegetables by Ionizing Radiation

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Studies on radiation preservation of food began in Japan 1956, being concerned with fish preservation by means of gamma rays. After that many works have been made in organizations of various fields as the radiation sources adequate for food preservation experiments were provided.

This paper presents some aspects of radiation preservation of fruits and vegetables in Japan.

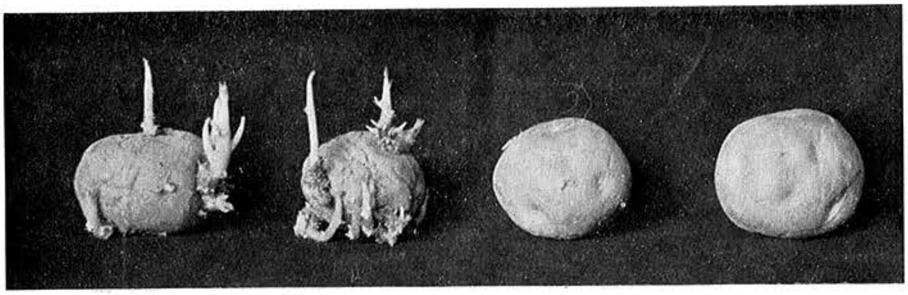
Control of sprouting

Potatoes, onions, garlic, chestnuts and other root crops lose their commercial value by sprouting or rooting during storage. The first study of gamma radiation on the improvement of storage quality of potatoes by Sparrow and Christensen (1954)[13] led to the application of radiation to the storage of other fruits and vegetables as well as the use of radiation to increase the storage life of potatoes. The result of their observations on the inhibition of sprouting was also confirmed on potatoes[7),16)], onions[7)], garlic[17)] and chestnuts[5),6)].

The experiments for sprout-inhibition of potatoes were carried out on the Danshaku[7)] and Shimabara varieties[16)]. It was found that potatoes retained good appearance (Fig. 1) and quality for several months at room temperature following irradiation of gamma rays.

However, irradiated potatoes have recently been found to become brown and to lose its commercial value[10),11),14)]. The browning induced by gamma radiation was partially observed around the vascular bundle of potatoes and the death of cells occurred. It was enhanced from 3 to 7 days after irradiation. This partial browning occurred in the potatoes irradiated with the doses of 10 Krad and 20 Krad within a month after harvest.

On the other hand, when the potatoes were



0 Krad 3 Krad 7 Krad 12 Krad

Fig. 1. Effect of gamma radiation on the sprouting of potatoes (stored at room temperature and photograghed 8 months after irradiation)

irradiated 2 months after harvest, little browning was observed in irradiated potatoes. Thus, it was indicated that irradiation at about 2 months after harvest was much more satisfactory than irradiation immediately after harvest.

It was noted that the content of ascorbic acid decreased in potatoes irradiated immediately after harvest, while the content of polyphenols increased in those within several days after irradiation, especially in the tissues of cortex and vascular bundle, and the activities of polyphenoloxidase and peroxidase also increased in those tissues of irradiated potatoes.

The sprouting of onions, Senshu-ki variety, was completely inhibited with the doses of 3 to 15 Krad of gamma irradiation during the rest period. However, it was found that the delay of irradiation after harvest reduced the effect of gamma radiation on the inhibition of sprouting[3),12)].

For instance, as shown in Table 1, irradiation after 3⅓ months of storage at room temperature (the time that inner buds of the bulbs were elongating to some extent) did not show a pronounced inhibition of sprouting at both doses of 7 and 15 Krad, indicating approximately 50 per cent of sprouting[3)]. Onions which were irradiated during the rest period and inhibited the sprouting retained its good quality for several months.

The similar tendency mentioned above was noted about garlic: Watanabe and Tozaki (1967)[17)] reported that irradiation before the end of August successfully prevented the sprouting at the doses of 3–4 Krad, but the irradiation experiment in the beginning of November failed to prevent the sprouting because of the onset of sprouting.

The chestnuts, Imakita variety, stored in the moist sawdust at room temperature after fumigation with carbon disulfide usually showed about 25 per cent of elongation of roots, 10 per cent of sprouting and only about 25 per cent of sound nuts in the middle of January (about 3⅓ months after harvest).

In contrast, the elongation of roots in 7 Krad-nuts was much suppressed with exception of 6 per cent, and 56 per cent of nuts were still consumable[5),6)].

Changes of some chemical substances in sprout-inhibited materials

The ascorbic acid content in potatoes, onions and chestnuts which were irradiated at the right time (period) for the sprout-inhibition was almost similar to unirradiated ones during the storage, respectively[5),7),14)].

The sugar content in materials contained starch increased in reducing type about irradiated potatoes and in total sugar about irradiated chestnuts temporarily after irradiation, which were followed by a decrease to reach an extent of the unirradiated ones, while there was no change of sugar content in onions by irradiation.

With potatoes a remarkable increase appeared in the sprout-inhibited potatoes of 7 and 12 Krad lots during the period of sprout-

Table 1. Effects of gamma radiation on the sprouting of onions (Senshu-ki variety)

Treatments and Dose (Krad)		Date of determination							
		6.24	9.26	10.7	10.28	11.15	11.24	2.20	2.24
Irradiated on the	0	0%		6.1	15.6	51.8		100.0	
20th day after	7	0		0	0	0		0	
harvest	15	0		0	0	0		0	
Irradiated after	0		0		14.3		41.0		89.0
3⅓ months of storage	7		0		12.0		29.8		52.6
at room temperature	15		0		10.4		34.1		46.5

ing in unirradiated ones, while the sprouted potatoes of the unirradiated and 3 Krad also showed some increase in spite of the consumption of sugars associated with sprouting.

It was believed that the accumulation of sugar which was derived from the degradation of starch due to lowering of storage temperature might have occurred in the sprout-inhibited potatoes. The lachrymatory character and the pungent flavor in onions slightly decreased by gamma irradiation (remarkably at over 70 Krad).

The growth substances would not have direct correlation to the mechanism of sprout-inhibition, since inner buds of irradiated onions contained both growth promotors and inhibitors to the same degree as the unirradiated ones 5 days after irradiation[7], although the level of growth promotors in the disks of onions (Fig. 2) was lower in irradiated onions than in unirradiated ones during the subsequent storage to irradiation[9].

Gamma irradiation at the low dose level would interfere with the nucleic acid metabolism in the meristem tissues such as the eyes of potatoes and the inner buds of onions.

The author and colleague found that the contents of ribosomal RNA and DNA in the eyes of potatoes and in the inner buds of onions were naturally lower in those irradiated meristem tissues than in those unirradiated ones at the start of growth of the eyes and the inner buds, respectively, and the increasing rate of soluble RNA which was synthesized with the start of growth was particularly suppressed in irradiated materials (Fig. 3)[4].

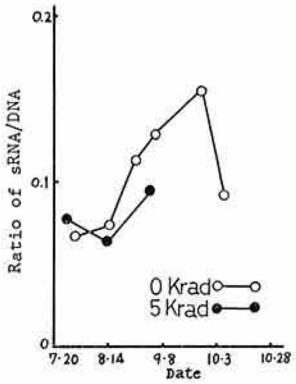


Fig. 3. Effects of gamma radiation on the ratio of sRNA/DNA in the inner buds of onions

Control of postharvest diseases

The possible application of ionizing radiation to disease control is evidently severely limited by the susceptibility of host plant tissues. Irradiation sufficient to inactivate pathogens would generally be expected to result in abnormal metabolism or physical and

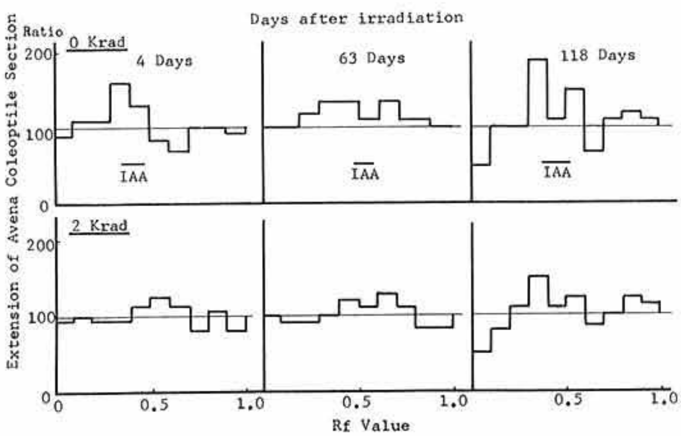


Fig. 2. Effect of gamma radiation on the growth substances of disks of onions (acidic fraction of ether extracts)

chemical changes of cell membrane. The tests of control of postharvest diseases were carried out on Satsuma oranges and strawberries.

Umeda et al. (1969)[15] reported that Japanese mandarin orange "Satsuma" was particularly susceptible to gamma rays and the adverse effects on flesh flavor and peel appearance were found when the fruits were subjected to 50 Krad or more, but the shallow irradiation with 1.0 MeV of cathode rays did not change the flavor acceptibility and appearance up to 250 Krad.

They also showed that the softening of peel and the destruction of oil-gland developed with higher dose during the post-irradiation storage and finally the browning of peel appeared, and that the deterioration was more severe with the shorter storage after harvest and the browning was accelerated at room temperature but repressed at 5°C storage. Analytical data of fruit flesh and juice showed no significant difference between irradiated and non-irradiated samples after the long term storage (Table 2).

With strawberries, Chachin et al. (1969)[1] reported that irradiation at the doses of 250 and 500 Krad strongly prevented mold growth at room temperature and 1–5°C of storage and that the decay of partially green berries was less than that of uniformly red berries, indicating that partially green berries would be more suitable for the radiation preservation of strawberries. The organoleptic evaluation indicated that the irradiation over the dose of 500 Krad caused more deterioration of the quality immediately after irradiation and during the storage.

Control of ripening in fruits

The author and colleague have investigated the physiological effects of gamma radiation on the ripening of fruits such as bananas, pears and tomatoes of the climacteric group and such as astringent persimmons and Satsuma oranges of the non-climacteric group.

It was recognized that irradiation dose for the delay of ripening was different by the kind of fruits and the stages of maturity and it was 50 Krad for mature green bananas, 200–250 Krad for mature green tomatoes and for slightly yellowish green pears.

The results described in Fig. 4 showed the delay of typical pattern of carbon dioxide production and the increase of sugars in banana fruits irradiated at the dose of 50 Krad.

With pears, it was found that irradiation at the dose of 250 Krad delayed the ethylene production during ripening as well as carbon dioxide production, and further investigations[2] have been carried out on the changes of respiratory metabolism, some organic acids, protein N and RNA during the ripening of

Table 2. Some analytical data on flesh and juice of irradiated Satsuma oranges (Unshu)

Sample & Group*	Number of sample	Average of wt. (g)	Flesh (%)	Juice (%)	Soluble solid (%)	Citric acid (%)	Dextrose /Acidity**
A-1	10	63.2	67	73	12.9	0.69	18.7
A-2	10	61.9	69	73	12.1	0.71	17.0
B-1	10	62.0	68	69	12.3	0.74	16.7
C-1	10	63.7	70	73	12.4	0.86	14.4
C-2	10	65.0	70	76	12.2	0.83	14.7
C-3	10	60.7	71	75	12.3	0.85	14.5
C-4	10	60.9	70	78	12.6	0.88	14.3
C-5	10	63.5	71	74	12.7	0.85	14.9
C-6	7	63.3	71	75	12.7	0.94	12.9

* Groups A and B were stored at 5°C for 5 months. Group C was stored at 5°C for 3 months. All samples were not inoculated with *Pen. sp.*

** Readings of hand refract-meter/Acid titration value

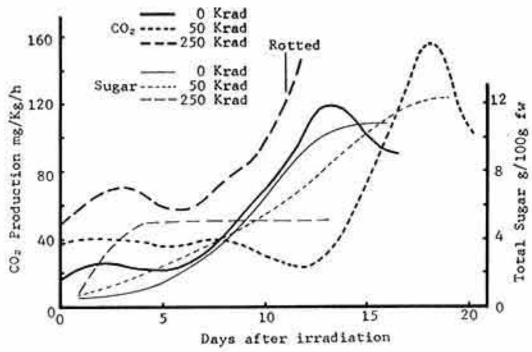


Fig. 4. Effects of gamma radiation on CO_2 production and total sugar content of banana fruits

Bartlett pears in order to study the mechanism of control of ripening by gamma radiation.

On the contrary, the ripening of astringent persimmons was accelerated with irradiation at the doses of 150–250 Krad, which suppressed the ripening of fruits of the climacteric group: the fruits irradiated at the doses of 150–250 Krad ripened within 5 days after irradiation and they became soft and less astringent with the advance of ripening with exception of the 1,000 Krad-fruits which the enzyme activities related to ripening would have been lowered by irradiation. Tannin content decreased considerably in irradiated and ripened fruits (Fig. 5)[8].

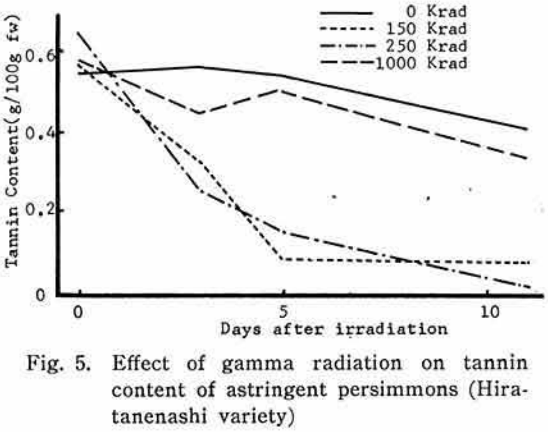


Fig. 5. Effect of gamma radiation on tannin content of astringent persimmons (Hiratanenashi variety)

Remarks

A petition on the gamma irradiation for the application of sprout-inhibition of potatoes has been already submitted to appropriate authorities in the Ministry of Public Welfare. This process will be permitted for commercial application in the near future in Japan as well as in the United States, USSR, Canada, etc. Then, more data are needed on the practical application of radurisation (irradiation for the decreasing of microorganisms in perishable foods such as strawberries, oranges, fresh fish, etc.) and of the delaying or accelerating of fruit ripening.

The use of gamma radiation for the sprout-inhibition of potatoes was permitted by Food Sanitation Council, and on August 31, 1972, a regulation was issued in the Federal Resister that radiation by Co may be used to prevent the sprouting of potatoes.

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