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SPROUT INHIBITION AND CHANGE IN ORGANIC COMPONENTS OF POTATO BY GAMMA-IRRADIATION

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Sprout Inhibition and Change in Organic Components of Potato by Gamma-Irradiation

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Radiation technology for sprout inhibition and change in organic components of potato by irradiation were investigated. Dose distribution in the package filled with potatoes (depth 45cm, density: $0.56 g/cm^3$) was measured using Fricke dosimeter. When the package was irradiated at dose rate of 5×10^5, 1×10^5 and 5×10^4 rad/hr, the dose uniformities were calculated as 1.79, 1.45 and 1.35, and the relative throughput capacities were 1.0, 0.26 and 0.14, respectively.

After 7 months storage, the sprout of potatoes was not observed at 10 krad irradiation while 57% of potatoes was sprouted at 5 krad. The contents of oxalic and malic acids were slightly increased by irradiation up to 100 krad while that of citric and succinic acids were not changed. The change in contents of these organic acids during storage was almost the same in both unirradiated and irradiated samples. Sucrose content was reached maximum after 8 days in 15 krad irradiated sample while it was increased through 40 days storage in 300 krad irradiated sample. The increase in sucrose contents by irradiation was higher in cortical tissue than in medullary tissue.

Keywords: Potato, Irradiation, Sprout Inhibition, Organic Acids,
Dose Distribution, Sugar Content

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γ 線照射による馬鈴薯の発芽防止と有機物の変化

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（1989年11月 1 日受理）

馬鈴薯の発芽防止における照射技術及び照射による馬鈴薯中の有機物の変化について検討した。馬鈴薯を詰めたパッケージ（深さ45cm，密度0.56 g／cm^3）内の線量分布をフリッケ線量計を用いて測定した。線量率5×10^5，1×10^5及び5×10^4 rad／hrで照射した時の線量均一度は各々1.79，1.45及び1.35，その時の相対処理量は1.0，0.26及び0.14と求められた。

7ケ月の貯蔵後，10krad照射区では発芽は認められなかったが，5kradでは57％が発芽した。蓚酸及びりんご酸は100kradまでの照射で多少増加したが，クエン酸やコハク酸に変化は認められなかった。これら有機酸の貯蔵中の変化は，照射，非照射ともにほぼ同じであった。蔗糖含量は15krad照射区では8日後に最大となったが，300krad照射試料では40日の貯蔵期間中増大した。この照射による蔗糖の増加は内部組織よりも外側組織で著しかった。

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Irradiation has several potential applications means of food treatment such as sprout inhibition, disinfestation, pasteurization and sterilization etc. The sprout inhibition of potato by irradiation has been most widely investigated in the world. For the commercialization of potato irradiation, the irradiation technology, especially dosimetry is important[1,2].

On the other hand, it is known that the irradiation causes several physiological changes in plants[3,4] and the interesting phenomena is the change in sugar content of irradiated potato[5-7] since the sugar plays an important role in browning of processed potato. Organic acids are also important constituents of plant foods influencing flavour, stability and keeping quality[6]. Contents of organic acids have been proposed as an index of maturity, ripeness or spoilage in certain commodity[8]. However, little information exists on individual organi acids in irradiated potato tuber.

In this experiment, at first the dose distribution, dose uniformity and throughput capacity of potato in package were studied, and then the change in organic materials such as sugar and organic acids of the irradiated potato during storage were investigated.

2. Materials and Methods

2.1 Materials

Potatoes of Danshaku variety were donated by Shihoro Agricultural Co-operative Association, Hokkaido, Japan.

2.2 Irradiation and storage

Potatoes were irradiated with a cobalt-60 gamma irradiator at a dose up to 300 krad (3 kGy). After irradiation potatoes were stored at 20°C and 10°C in plastic basket.

2.3 Observation for spoilage and sprouting

Potatoes were observed visually and by touching to determine their spoilage and sprouting in every month during storage.

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2.4 Extraction of organic acids and sucrose

Ten different potatoes were evaluated for individual organic acid content in potato. Unpeeled tubers were longitudinally cut in half and uniformly grated over the entire surface to a depth of ca. 3 mm to obtain the tissue representative of the whole tuber. Grated tissues from different potatoes were mixed thoroughly to minimize tuber to tuber variability. Mixed tissue (10 g) was homogenized in 80% ethanol by a universal homogenizer at a high speed for 2 min. The resulting slurry was then boiled for 15 min, immediately cooled and filtered with Toyo No. 101 filter paper. The residue and original container were washed with additional 80% ethanol and made a final volume of 100 ml.

For the extraction of sucrose the filtrate was then evaporated by vacuum evaporator up to a volume of 10 ml and filtered again with Toyo No.5c filter paper. An aliquot was then filtered with a 0.45 μm Fluoropore membrane to remove particulate impurities before HPLC analysis.

2.5 Preparation of organic acid and sucrose standard solution

Analytical grade organic acids and sucrose were dissolved in 80% ethanol, filtered, and finally ultrafiltered before injection to HPLC.

2.6 High Performance Liquid Chromatography (HPLC)

An HPLC analysis of organic acids[8)] was performed on a Shimadzu LC-3A liquid chromatograph with an ultraviolet detector at a fixed wavelength of 214 nm. Organic acids were separated using a 300 × 7.8 mm Aminex HPX-87H column (Bio-Rad Lab. USA) at 75°C. The mobile phase was $0.0008NH_2SO_4$ and flow rate was 0.8 ml/min.

For the analysis of sucrose the column used was PNH_2-10/S 2504 and the eluent was acetonitrile-water (75/25)[7)]. The flow rate was 1 ml/min and the sucrose was detected by a R.I. detector.

3. Results and Discussion

3.1 Dose distribution in the package with potatoes

Fricke dosimetry is one of the easiest methods to measure the low dose for food irradiation[9)] and widely used as a reference dosimeter[10)]. Therefore, the Fricke dosimeter was mainly used to calculate dose distribution in the potato package using a lower concentration of Fe^{2+}(0.001M).

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A carton box of dimension 45(width) × 30(height) × 30(depth) cm was used for this experiment. A total 27 dosimeters were placed in the box as shown in Fig. 1 and filled with potatoes. The box was then irradiated with a dose rate of 1×10^5 rad/hr from both sides. The absorbed dose is shown in Table 1. Dose distribution in the potato package is almost uniform at all points except tube No. 2 and 16. Tube 2 was the lowest absorbed dose whereas tube 16 was the highest. The dose uniformity in the potato package was calculated as 1.23 using these values.

3.2 Dose uniformity and throughput capacity on potato irradiation

Two dosimeters were located at each distance in depth direction (0, 11, 22, 33 and 44 cm from front surface of the package) and the boxes were then irradiated at three different dose rates of 5×10^5, 1×10^5 and 5×10^4 rad/hr. Front surface of the boxes were set at each dose rate positions during irradiation and the results of absorbed dose (in depth direction) were shown in Table 2. The absorbed dose values of front, middle and back side of the packages were taken for the determination of dose uniformity at different dose rates. Dose uniformity at different dose rates of 5×10^5, 1×10^5 and 5×10^4 are 1.79, 1.47 and 1.29, respectively and it is observed that the value of dose uniformity is higher at higher dose rate.

Throughput capacity is calculated from this result and it is observed that throughput capacity is higher at higher dose rate. Throughput capacity is one of the important considering factors for the commercial irradiation facility. If throughput capacity is bigger, the irradiation cost is cheaper. At a dose rate of 5×10^5 rad/hr, 100 packages are possible to irradiate at a certain time, whereas 26 and 14 packages are possible to irradiate at 1×10^5 and 5×10^4 rad/hr respectively, if the maximum dose assumed to be the same. So the throughput capacity at 5×10^5 rad/hr is 4 times bigger than that at 1×10^5 rad/hr. At lower dose rate the dose uniformity is better than higher dose rate. Therefore, it is necessary to choose the suitable dose rate which is possible to irradiate within a limited dose uniformity.

3.3 Effect of irradiation on sprouting and rotting

Irradiated potatoes were stored at room temperature on a plastic basket and observed visually and by touching to check the spoilage and sprouting in every month. After one month storage, 2 – 3 potatoes in each group (unirradiated, 5 and 10 krad irradiated) were found injured and partially spoiled. After they were discarded at that time, there were no spoilage of potato throughout the storage period.

Table 3 shows the sprouting of potato during storage. The sprouting of unirradiated potato began in October (one month storage) and 34% of potato were sprouted. In December (three months storage) 100% of the unirradiated potato were sprouted whereas the potatoes irradiated by 5 krad sprouting in October (0.5%) and 57% of them were sprouted in April (seven months storage). The sprouting of 10 krad irradiated potatoes was not observed until April (seven months storage).

The skin of unirradiated potato became shrinked after 4 months of storage while that of 10 krad irradiated sample were still fresh. So it is concluded that 10 krad is effective for sprout inhibition of potato as well as keeping them in good quality. Whereas, 5 krad is not enough but effective to delay the sprouting for few months.

3.4 Change in organic acid contents

3.4.1 Irradiation effect on organic acid contents

Figure 2 illustrates a typical chromatogram of organic acids in potato. The first peak is water, which is closely followed by oxalic acid at 4.5 min. Oxalic acid has a strong absorption at 214 nm and are the second major organic acid in potato. Figure 3 shows that oxalic acid gradually increased by irradiation up to 15 krad then decreased a little at 100 krad. The peak of the citric acid comes at 5.3 min and it is the major organic acid in potato. There is no effect of irradiation on the citric acid. The next organic acid found in potato is malic acid which elutes at 6.27 min. The peak at 7.07 min was also observed in standard malic acid. Therefore, it is considered that the peak must be impurity derived from malic acid. As the absorbance at 214 nm of this materials was very high, the contents were small even at high peak. The malic acid increased gradually with an increase in irradiation dose. Succinic acid eluted at 7.9 min is followed by an unknown peak at 9.8 min. An asymmetric ethanol peak at 16.7 min follows a small unknown peak at 13.5 min.

3.4.2 Storage effect on organic acid contents after irradiation

Organic acids were analysed in every month during storage. Figure 4 shows the change in oxalic acid during storage for 7 months. It is observed that the acid increased rapidly in the first month and then gradually decreased to that of unirradiated potato. The sprouting of potato also starts after one month of storage. Therefore, it is supposed that the sudden increase of oxalic acid is due to the sprouting of potato. But the oxalic acid did not increase when the sprouting of 5 krad irradiated potato started after 3 months storage. Further investigation is necessary to clarify the relationship of sprouting and increasing in the oxalic acid.

Figure 5 shows that malic acid gradually increased but the difference between irradiated and unirradiated potato was small throughout the whole storage period. Citric acid and succinic acid contents did not change during storage (Fig. 6 and 7).

3.5 Change in sucrose content after irradiation

The potatoes were irradiated at a dose of 15 and 300 krad and sucrose contents were analysed separately from cortical and medullary tissue of potato during storage at 10 and 20°C.

Figure 8 shows the change in sucrose content during storage at 20°C. The sucrose content of cortical tissue irradiated with a dose of 300 krad increased and reached to 23.9 mg/g after 8 days. This content was 10 times of unirradiated samples (2.3 mg/g), while that of the medullary tissue continued to increase during 20 days. The content of both tissues of the tuber irradiated at 15 krad increased and reached maximum to 8.5 mg/g after 8 days, and then it is gradually decreased up to 20 days. While, the content of the unirradiated tuber remain almost the same during the whole storage period. From 20 to 40 days there is no change in sucrose contents in any samples.

Sucrose contents of tuber stored at 10°C is shown in Fig. 9. Sucrose of cortical tissue of 300 krad irradiated sample continued to increase for 20 days and the content of the medullary tissue continued to increase up to 22.5 mg/g until 40 days while the content of unirradiated sample changed only a little through 40 days.

These results show that the sucrose of the irradiated potato increased rapidly for first 4 days after irradiation in both temperature and the sucrose of the medullary tissue increased slowly than that of cortical tissue.

Hayashi and Kawashima[7] reported that the accumulation of sucrose in irradiated sweet potato roots and potato tubers depends on the irradiation dose and the maximum sucrose content of potato tuber was obtained at 300 krad. They observed that the accumulation of sucrose in irradiated sweet potato roots accompanied with the decreased in starch contents and suggested that gamma-irradiation triggered the conversion of starch into sucrose. They used the whole tuber for analysis but the sucrose of cortical and medullary tissue were separately analysed in this experiment. The results in cortical tissue (the sucrose content increased for one week, slightly decreased in the second and third week then leveled off) show the same tendency as their results. While the content of sucrose in medullary tissue continued to increase up to third week and leveled off at 40 days. The content of cortical tissue increased rapidly and was higher than that of medullary tissue. From these results it is considered that the higher browning of the potato chips in cortical tissue corresponds with the higher sucrose contents.

References

1) T. Kume, H. Tachibana, S. Aoki and T. Sato, Nippon Shokuhin Kogyo Gakkaishi 20, 492 (1973).
2) T. Kume, H. Tachibana, S. Aoki and T. Sato, JAERI-M 6408 (1976).
3) B.J. Romani, Radiat. Bot., 6, 87 (1966).
4) A.H. Haber, Ann. Rev. Plant Physiol., 19, 463 (1968).
5) W.G. Burton, Potato Research, 18, 109 (1975).
6) D.P. Becker, M. Meier and J.C. Somogyi, Mitt. Gebiete Lbensm. Hyg. 70, 153 (1979).
7) T. Hayashi and K. Kawashima, Agric. Biol. Chem., 46, 1475 (1982).
8) David H. Picha, J. Agric. Food Chem., 33, 743 (1985).
9) T. Kume, H. Tachibana and M. Takehisha, JAERI-M 82-100 (1982).
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Table 1 Distribution of Dose in Potato Package

Tube No.	Absorbed Dose	Tube No.	Absorbed Dose
1	0.92	15	0.96
2	0.81	16	1.00
3	0.91	17	0.92
4	0.91	18	0.99
5	0.86	19	0.96
6	0.90	20	0.84
7	0.92	21	0.96
8	0.87	22	0.98
9	0.94	23	0.99
10	0.98	24	0.96
11	0.87	25	0.94
12	0.96	26	0.90
13	0.94	27	0.98
14	0.88		

The middle position of box was fixed at dose rate 1×10^5 rad /hr.
The density was 0.56 g/cm^3 (22.55 kg / 40500 cm^3).
Dose uniformity, $U = D_{max}/D_{min} = 1.00/0.806 = 1.24$.

Table 2 Determination of Dose Uniformity and Relative Throughput Capacity

Dose rate (rad/hr)	D_0	D_{22}	D_{44}	Dose uniformity	Throughput capacity
5×10^5	1.0	0.31	0.11	1.79	1.0
1×10^5	1.0	0.41	0.19	1.45	0.26
5×10^4	1.0	0.44	0.19	1.35	0.14

1) D_0, D_{22} and D_{44} show the relative doses at the distance from the source 0, 22 and 44 cm, respectively.
2) Dose uniformity was calculated as $D_0 + D_{44} / 2 \times D_{22}$

Table 3 Sprouting of Irradiated Potato during Storage

Month	Dose (krad)	Number of potato	Number of sprouted potato	Percent of sprout	Sprout length (mm)
Oct.	0	214	74	34	5
	5	212	1	0.5	0
	10	215	0	0	0
Nov.	0	210	206	98	5
	5	208	1	0.5	3
	10	211	0	0	0
Dec.	0	206	206	100	10
	5	204	2	1	5
	10	207	0	0	0
Jan.	0	202	202	100	20
	5	200	16	8	5
	10	203	0	0	0
Feb.	0	198	198	100	20
	5	196	48	24	10
	10	199	0	0	0
Mar.	0	194	194	100	30
	5	192	72	37	20
	10	195	0	0	0
Apr.	0	190	190	100	50
	5	188	109	57	30
	10	191	0	0	0

Potatoes were irradiated at dose rate of 1×10^5 rad/hr and dose uniformity was 1.25.

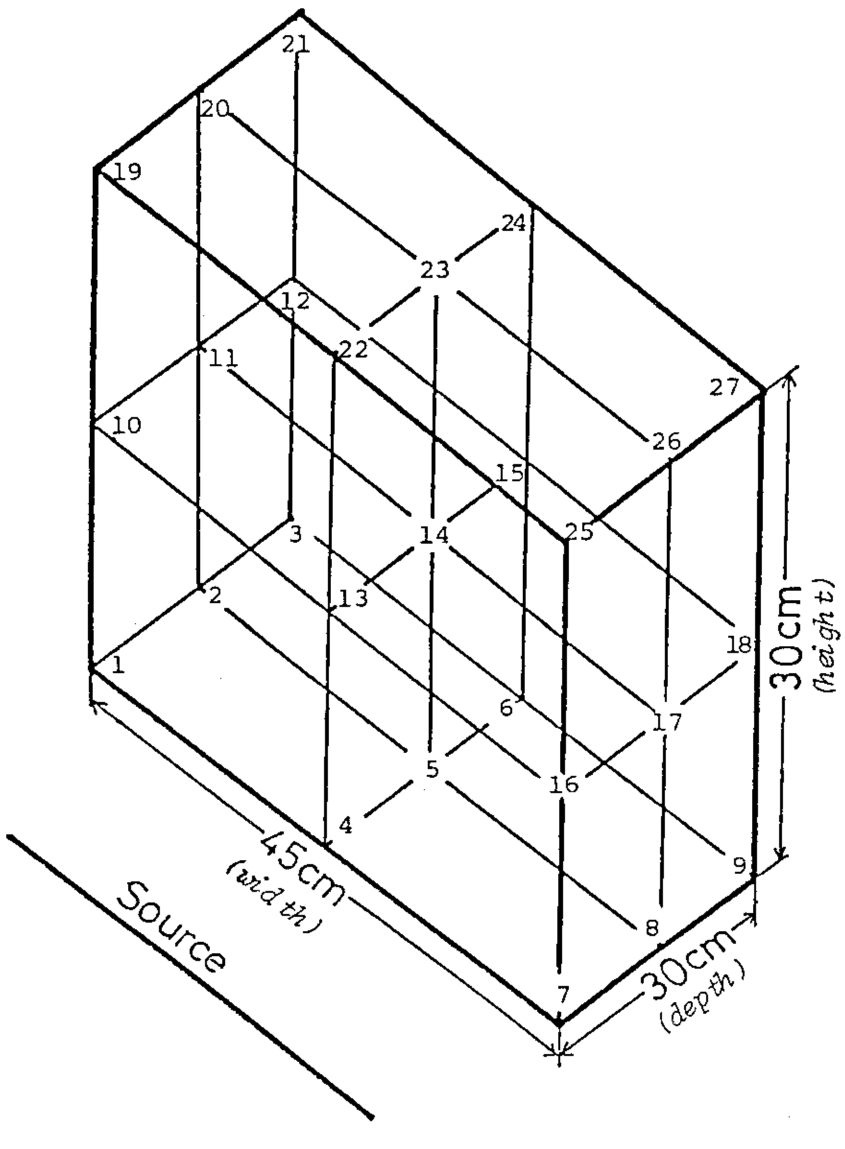

Fig. 1 Position of Dosimeters in Package Filled with Potatoes

The package was irradiated from both sides for 6 min at the dose rate of 1×10^5 rad/hr. The average density was 0.55 g/cm^3.

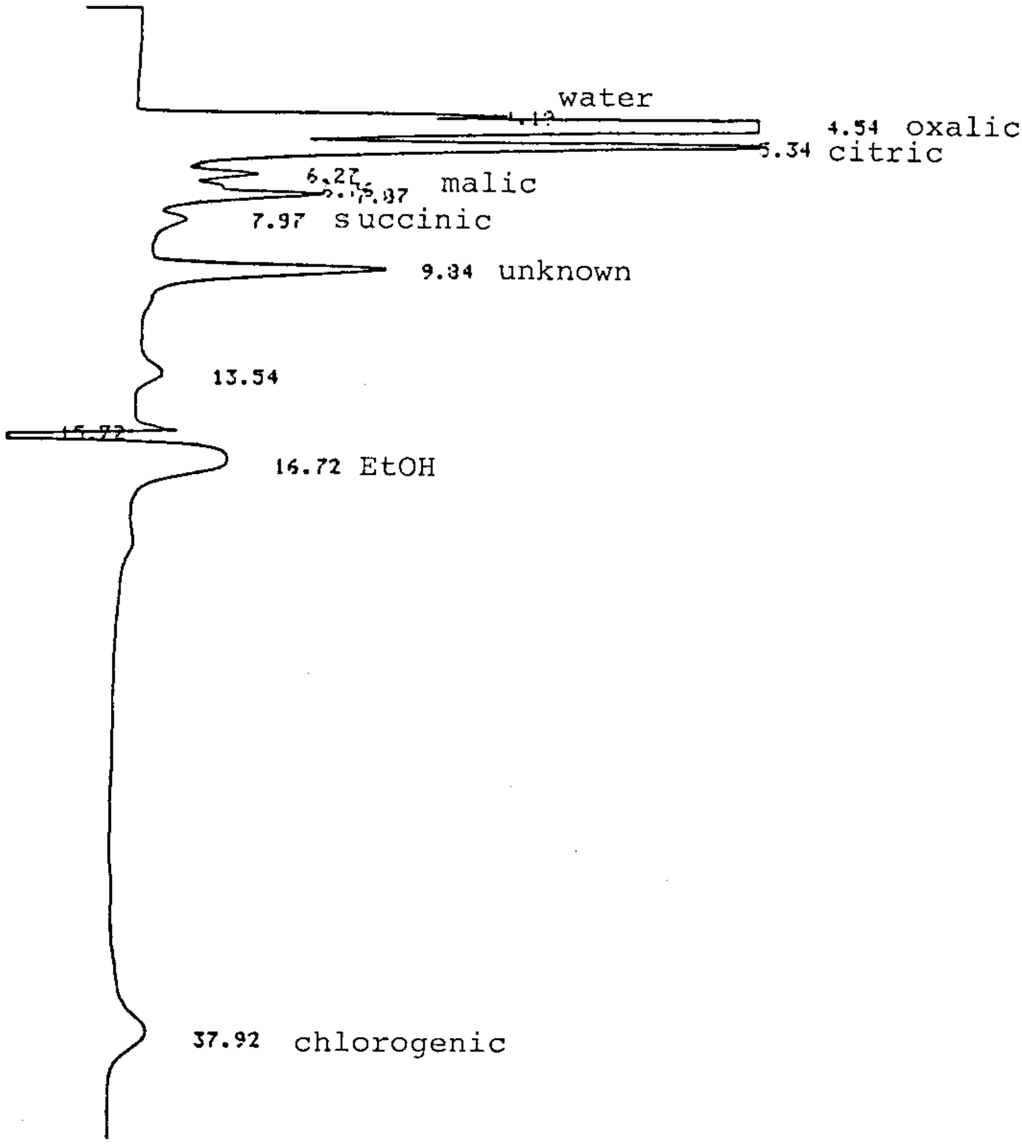

Fig. 2 HPLC Chromatogram of Organic Acids Extracted from Potato

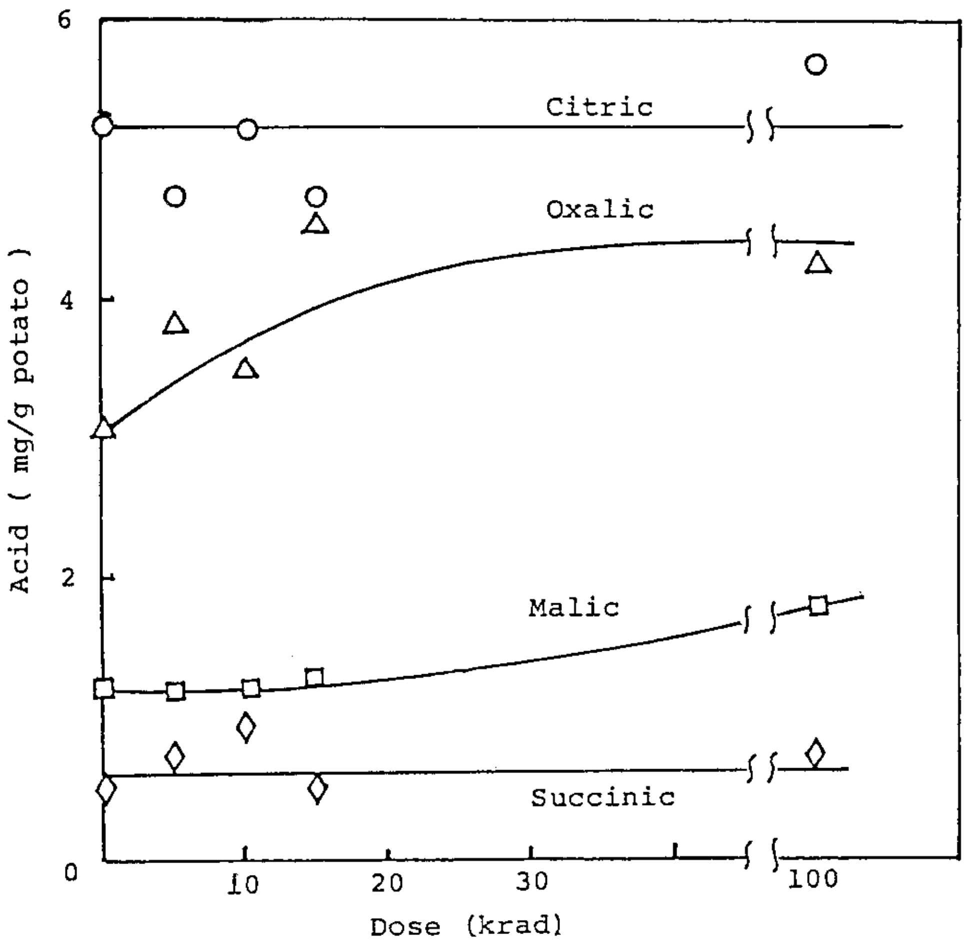

Fig. 3 Change in Organic Acid Contents in Potato Just After Irradiation

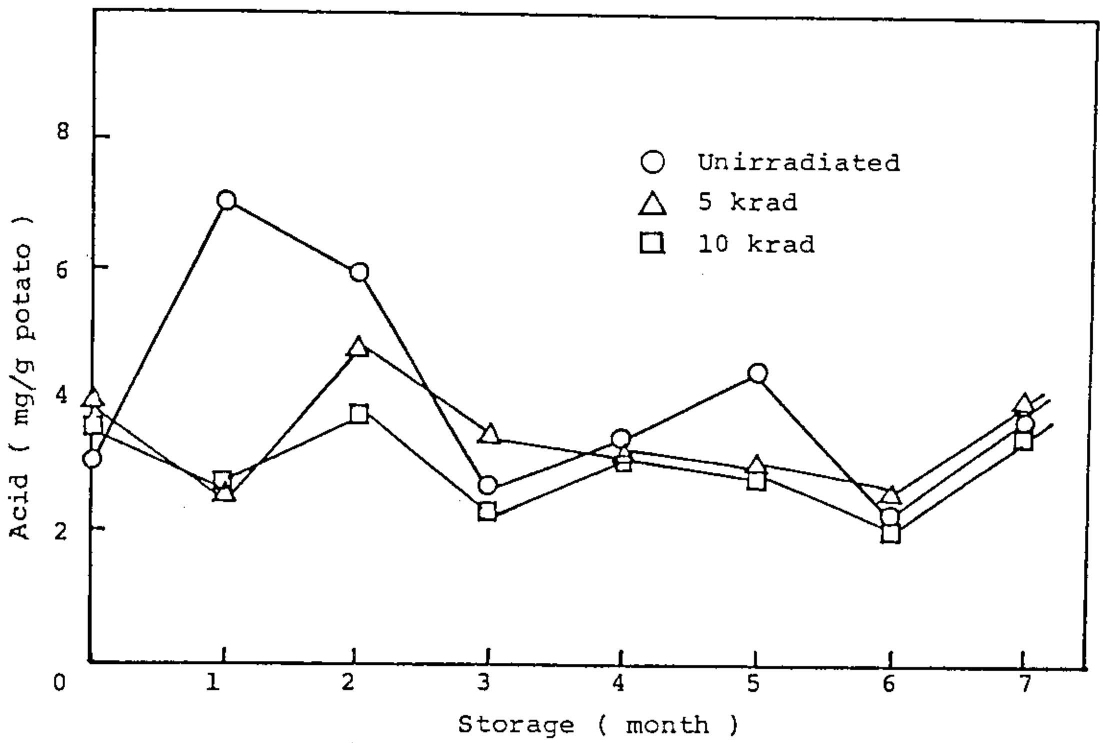

Fig. 4 Change in Oxalic Acid Contents During Storage

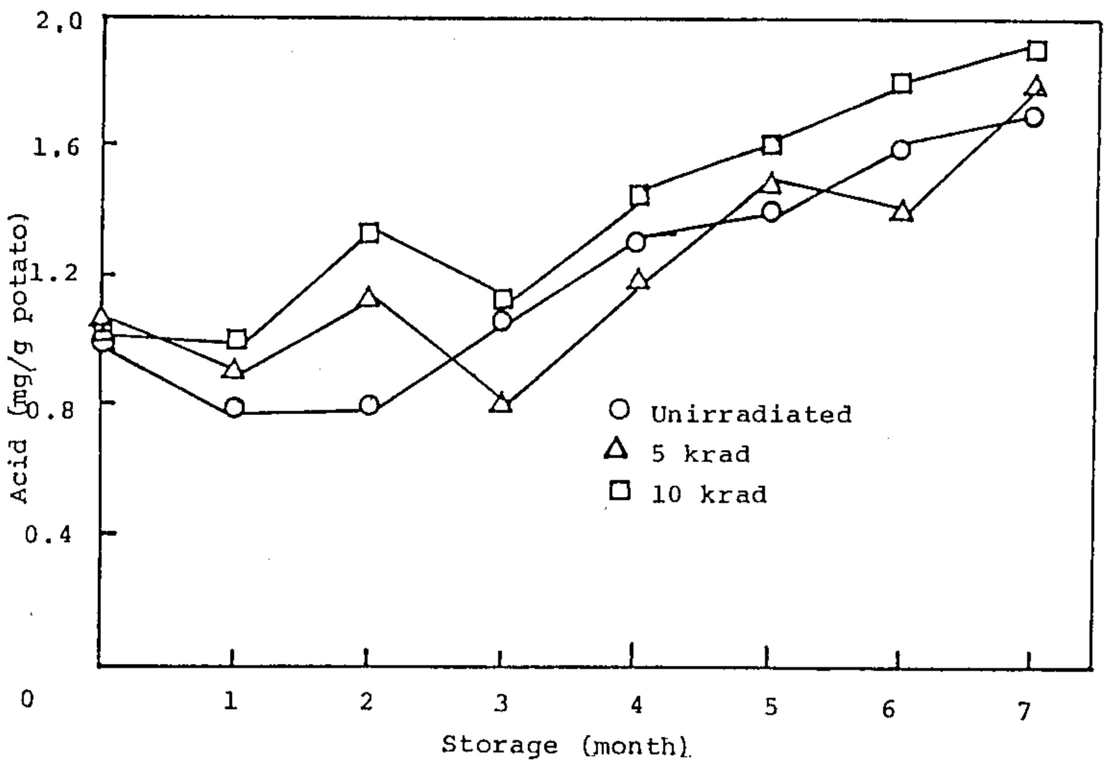

Fig. 5 Change in Malic Acid Contents During Storage

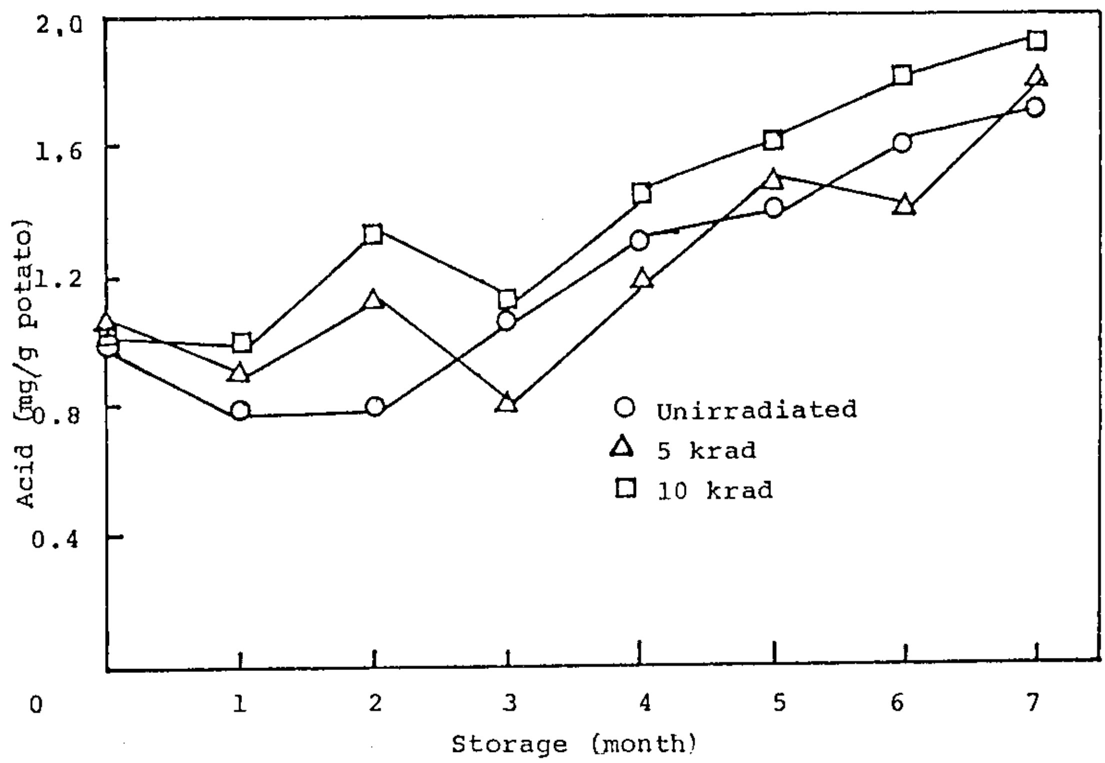

Fig. 6 Change in Citric Acid Contents During Storage

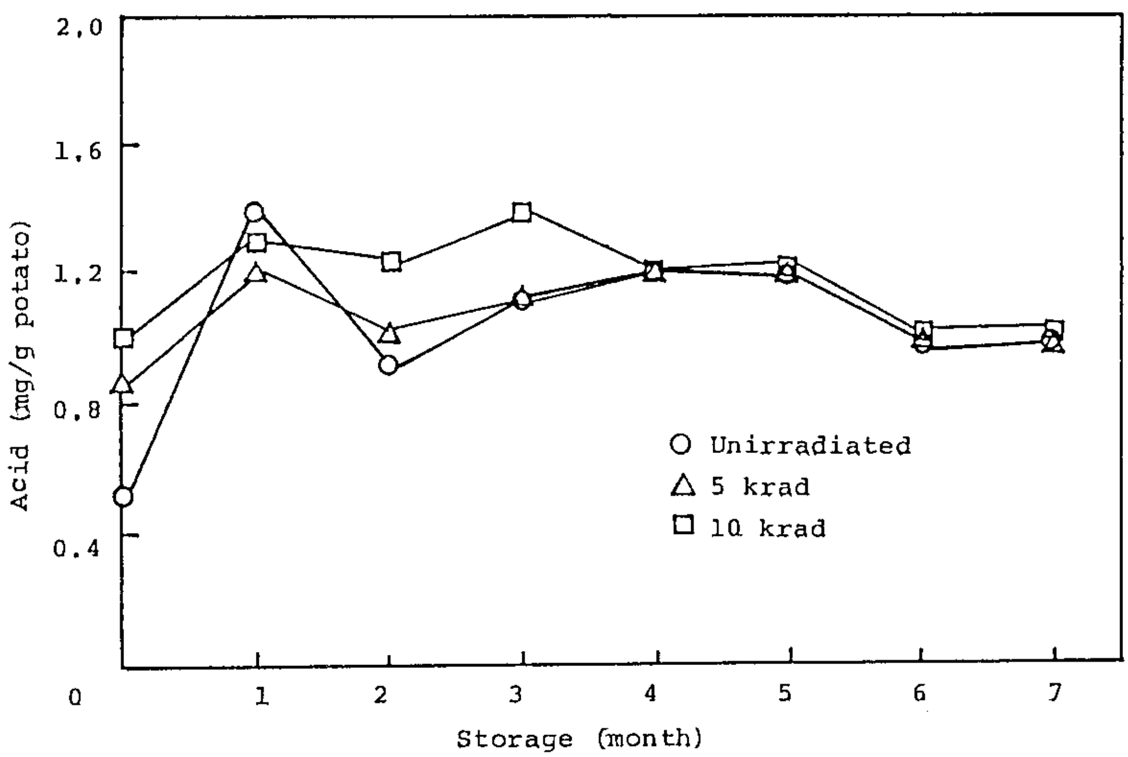

Fig. 7 Change in Succinic Acid Contents During Storage

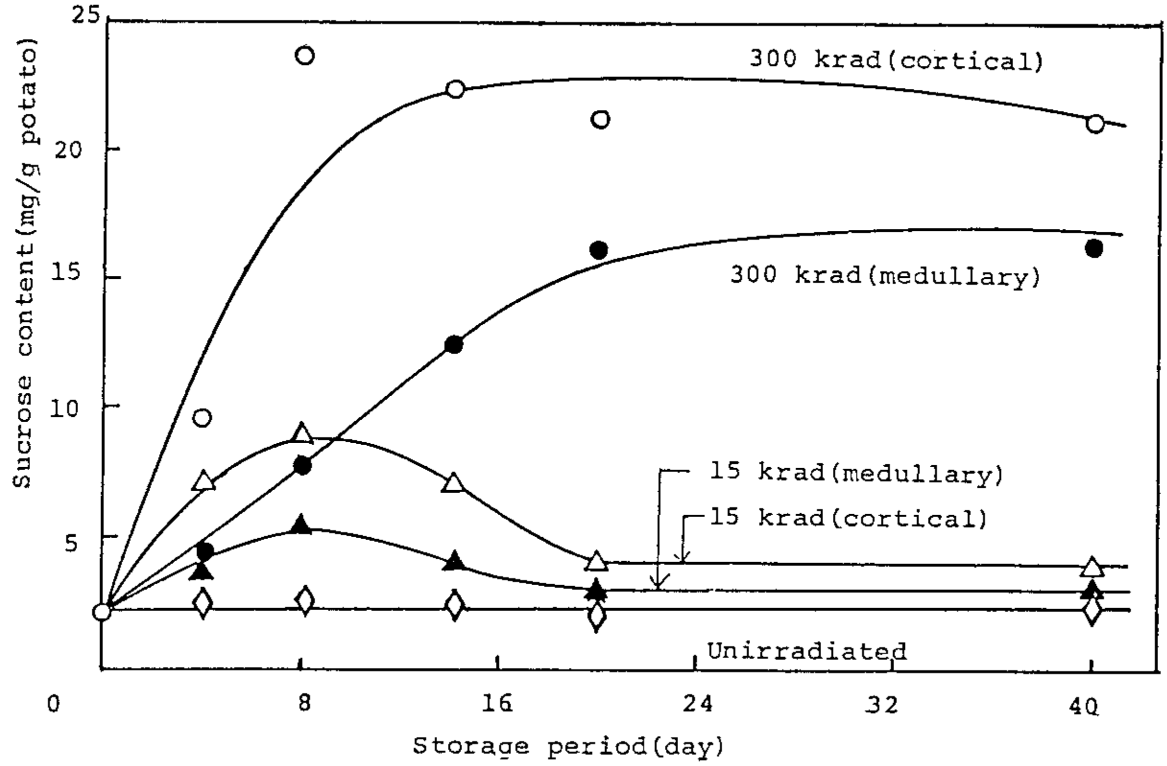

Fig. 8 Change in Sucrose Contents of Potato Stored at 20°C

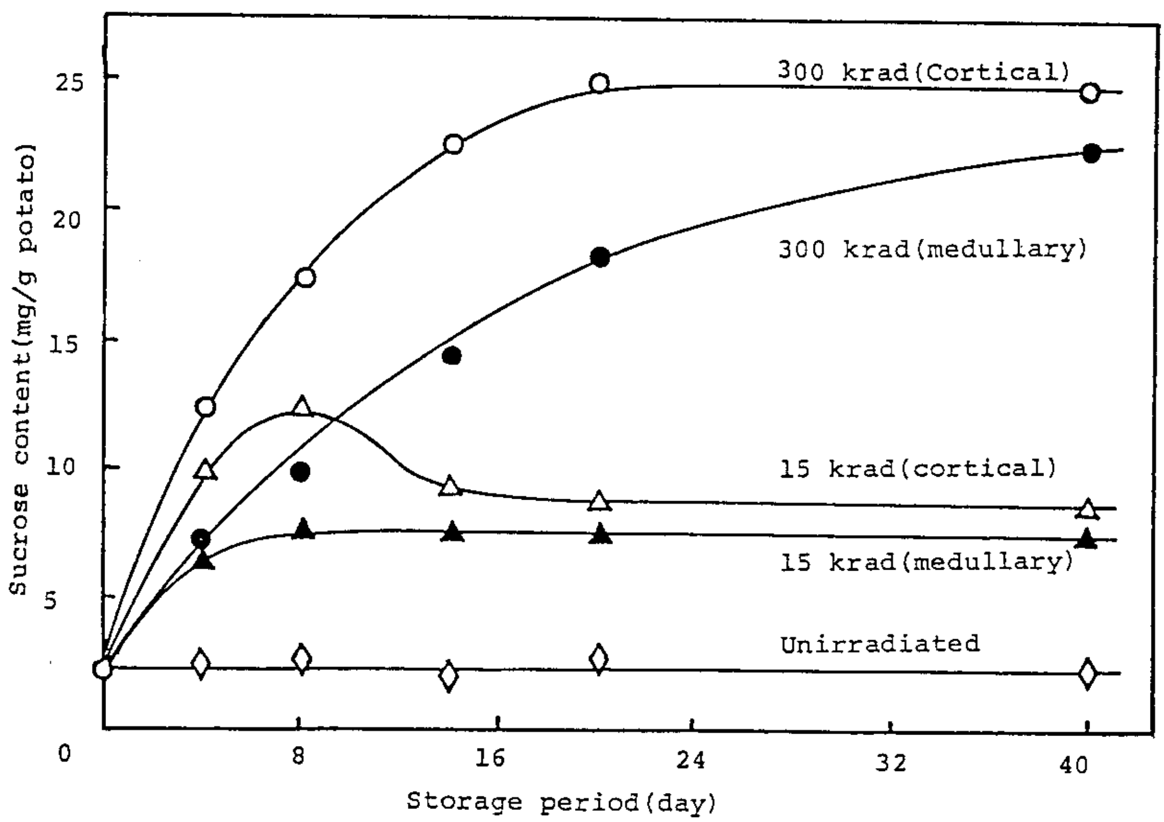

Fig. 9 Change in Sucrose Contents of Potato Stored at 10°C