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발아식품의 품질보존을 위한 전리방사선의 이용

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Utilization of Ionizing Radiation on the Preservation of Sprouting Foods

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Summary

This research was attempted in order to develop a long-term storage method for sprouting foods such as potatoes, onions, garlic and chestnuts using Co-60 gamma irradiation combined with a natural low temperature. The sprouting of the irradiated groups, 150 Gy in potatoes, 50 Gy in onions and garlic, and 250 Gy in chestnuts was almost completely inhibited until 8 to 10 months of storage. The rotting rate of loss of weight influenced a little by irradiation with a sprout inhibiting dose, and the weight of loss of the optimum dose irradiated groups was reduced by about 6 to 24 % as against that of the nonirradiated in the four stored foods. The chemical components relating to the quality of sprouting foods were better retained in the irradiated groups than in the nonirradiated until the latter period of storage. Therefore, it was shown that the long term storage of sprouting foods is possible using gamma irradiation of 50 to 150 Gy for potatoes, onions, and garlic and 250 Gy for chestnuts followed by storage at a natural low temperature (10 ± 5 ℃, R.H. 75-85 %).

Introduction

The major sprouting foods eaten in Korea are potatoes, onions, garlic and chestnuts, and the production of these foods has annually increased in recent year.[17] Owing to the change of eating habits and gross demands for fresh foods or materials for mass processing, a stable supply of raw materials is needed year round.

The over-production of sprouting foods, however, brings about a sudden fall in their prices at harvest time, and the massive loss of foods during storage and the supply deficiency resulting from the absence of economical storage methods for sprouting foods have resulted in an abnormal jump at the market price in the off-season by 2 to 3 times compared with that of harvest time every year.[1] Therefore, the demand for the development of an economically feasible storage method which prevents the loss of foods during storage, stabilizes the price fluctuation and provides steady supply of raw materials for processing the whole year round is urgent.

Root and bulb crops such as potatoes, onions and garlic have a given dormant period of 2 to 3 months after harvest, and after that period, almost all of products sprout and the additional loss due to spoilage and weight loss is significant.

Therefore, in order to prevent losses of these foods during storage, cool temperature (0-5 ℃) storage methods [9,15] and chemical treatments (maleic hydrazide, MH)[4] were studied and then partially implemented in commercial operations in Korea. However, these methods are not sutitable for the long term storage of sprouting foods because of the ineffectiveness and problems of chemical residues, storage cost and capacity.

Since Sparrow and Christensen[16] first reported that Co-60 gamma radiation had an effect on sprout inhibition in potato tubers, many workers[12,2] have indicated the effectiveness of gamma irradiation for the storage of other sprouting foods, and recently, the worldwide uses of gamma irradiation to inhibit the sprouting of roor crops ; prevent the reproduction of insects ; kill insects and parasites ; inactivate bacteria, spores, and moulds ; delay ripening in fruits and improve technological properties of food have been becoming the only viable alternative to traditional methods of food preservation.

This experiment, therefore, was attempted on the model business scale for the commercial storage of sprouting foods by irradiation in Korea.

Materials and Methods

"Irish Cobbler", potatoes (*Solanum tuberosum*), "Yong An Hwang", onions (*Allium cepa*) and "Korean local late variety", garlic (*Allium sativum*), which obtained from a major producing district, Changnyung, on 20 June 1982, were cured in circulating air of 22-25 ℃ and a relative humidity (RH) of 60-70% for 2-3 weeks after harvest. Also, "Eun Ki", chestnuts (*Castanea mollissima*) were obtained from Kwangyang on 15 October 1982 and fumigated with CS_2 gas after selection by 6° Baume brine. Approximately 1,400 *kg* of potatoes and onions, respectively and 90 bundles (100 bulbs per bundle) of garlic were irradiated with doses of 50, 100 and 150 Gy, respectively and 900 *kg* of chestnuts was irradiated with doses of 150, 200 and 250 Gy. A Co-60 gamma irradiator (U. K., 25 Gy/hr) was used in each case.

The nonirradiated and irradiated groups were packaged individually in units of 20 to 25 *kg* in perforated plastic boxes, and the chestnuts were packaged layer upon layer with sawdust containing 50% moisture. The samples were stored in a cellar type natural low temperature storage room (4.5 × 6.5 × 2.5 *m*) at 10 ± 5 ℃ and a R.H. of 75-85% for 8 to 10 months. The storage conditions were controlled with a ventilator and a humidifier (Keumsung Co., LTD.).

All physicochemical properties were investigated at two-month intervals during storage. The sprouting of potatoes, onions and chestnuts was reckoned as more than 1 *mm* length of sprout growth and indicated as the percentage. In garlic, however, sprouting rate was expressed as the percentage of sprout length per total clove length. The weight change of the samples was calculated as a cumultative percentage of weight loss and rotting rate was expressed as the percentage of decayed number per 100 samples. Moisture content was determined according to the 105 ℃ dry method[13] and total and reducing sugars were measured by the modified Somogyi method.[8] The content of ascorbic acid was determined according to 2, 4-dinitrophenylhydrazine colorimetry[12].

Results and Discussions

During the storage period, the sprouting rate of potatoes, onions, garlic and chetnuts according to irradiation dose is shown in Table 1.

The nonirradiated groups of each sample all sprouted after 4 to 8 months of storage, while in the irradiated groups, 150 Gy in potatoes, 50 Gy in onions and garlic and 250 Gy in chestnuts, sprouting was almost completely inhibited until 8 to 10 months of storage.

It was reported that sprout inhibition by gamma irradiation was influenced by the physiological state of the sample at the time of irradiation, the

Table 1. Sprouting rate of irradiated sprouting foods during storage

(Uuit : %)

Period (month) \ Item / Dose (GY)	Potatoes				Onions				Garlic *				Chestnuts			
	0	50	100	150	0	50	100	150	0	50	100	150	0	150	200	250
0	0	0	0	0	0	0	0	0	19.2	19.2	19.2	19.2	0	0	0	0
2	24.2	25.4	16.7	0	18.3	0	0	0	27.1	25.1	23.2	23.4	12.2	5.4	2.6	0
4	79.0	82.0	60.0	0	47.3	0	0	0	65.6	58.6	58.8	59.4	100.0	83.2	41.8	2.0
6	100.0	100.0	83.0	3.3	100.0	0	0	0	93.6	68.2	67.8	68.4	-	100.0	92.8	6.0
8	-		90.0	3.3	-	0	0	0	97.3	70.2	68.7	68.9	-	-	100.0	20.2
10	-		90.0	3.3	-	0	0	0	135.0	76.1	71.2	70.8	-	-	-	-

* The elongation ratio of an internal sprout leaf to clove length

radiation dose and the storage temperature after irradiation[18] and the results observed agreed with the reports of Khan et al[8] and Cho et al.[2] In order to reduce losses due to rot attack, stored samples should be cleaned and well-ripened before irradiation. The rotting rate increased with storage time, and at the latter stage of storage, the percentage of rotted samples was considerably higher in the nonirradiated groups than in the irradiated ones in potatoes, onions and garlic, although there was no significant difference between the nonirradiated and irradiated groups in chestnuts (Table 2).

The weight loss of sprouting foods during storage was slightly decreased with the increase of irradiation dose in all stored groups (Table 3). As inicated by Hendel and Burr[2] and Mathur[11], the physiological losses in weight are mainly due to transpiration and respiration, and so it seems that the weight loss of sprouting foods can't be affected by the irradiation dose for sprout inhibition if the storage temperature and the relative humidity are well controlled.

As the storage period was elapsed, the moisture content of the potatoes slightly decreased in all groups, whereas that of onions, garlic and chestnuts was relatively constant except for the decrease of content along with sprouting in garlic at the end of storage period (Table 4). These resu-

Table 2. Rotting rate of irradiated sprouting foods during storage

(Unit : %)

Period (month) \ Item / Dose (GY)	Potatoes				Onions				Garlic				Chestnuts			
	0	50	100	150	0	50	100	150	0	50	100	150	0	150	200	250
0	0	0	0	0	0	0	0	0	3.2	3.2	3.2	3.2	0	0	0	0
2	1.0	0	0	0	6.6	10.0	3.3	3.3	66.1	14.5	11.2	10.4	2.2	2.0	0.8	2.4
4	2.4	0	0	0	10.0	13.3	6.7	3.3	18.4	14.9	12.0	11.1	4.8	4.4	4.2	4.6
6	3.3	1.1	0	0	13.3	13.4	6.7	6.7	21.4	17.5	12.7	12.0	16.4	14.2	15.8	13.4
8	6.7	3.3	3.3	3.3	66.3	20.7	17.7	18.3	28.5	18.3	14.3	12.4	30.8	31.2	32.1	32.2
10	20.1	17.4	17.8	5.7	100.1	50.3	41.7	52.7	83.5	29.3	27.4	30.1	-	-	-	-

Table 3. Weight loss of irradiated sprouting foods during storage (Unit : %)

Period (month) \ Dose (GY) \ Item	Potatoes 0	Potatoes 50	Potatoes 100	Potatoes 150	Onions 0	Onions 50	Onions 100	Onions 150	Garlic 0	Garlic 50	Garlic 100	Garlic 150	Chestnuts 0	Chestnuts 150	Chestnuts 200	Chestnuts 250
0	2.4	2.5	1.5	0	3.7	1.8	1.8	2.0	14.1	12.7	12.3	12.6	+0.5	+0.4	+0.6	+0.5
2	2.8	3.0	2.4	1.0	8.6	2.5	2.6	2.8	19.2	18.7	17.9	17.7	1.7	+0.4	+0.2	+0.3
4	4.9	5.9	4.1	1.8	14.8	3.1	2.9	4.7	22.5	20.4	18.9	19.0	3.8	0.4	0.2	0.1
6	8.4	7.9	6.4	2.6	-	7.7	5.9	10.6	30.7	24.5	21.3	22.1	6.9	1.4	1.3	1.4
8	15.7	12.8	11.3	6.1	-	-	-	-	53.8	30.6	30.0	29.9	-	-	-	-

Table 4. Changes in moisture content of irradiated sprouting foods during storage (Unit : %)

Period (month) \ Dose (GY) \ Item	Potatoes 0	Potatoes 50	Potatoes 100	Potatoes 150	Onions 0	Onions 50	Onions 100	Onions 150	Garlic 0	Garlic 50	Garlic 100	Garlic 150	Chestnuts 0	Chestnuts 150	Chestnuts 200	Chestnuts 250
0	77.1	78.0	77.7	77.2	89.6	89.6	90.5	90.1	66.6	66.7	67.0	67.0	61.2	61.2	61.9	61.5
2	77.4	76.0	76.0	77.1	90.3	91.2	90.1	90.9	67.8	66.9	67.6	67.6	61.8	61.7	64.1	63.2
4	77.9	76.1	76.4	76.2	91.0	91.8	91.5	91.8	67.9	67.4	67.2	67.6	58.8	60.6	62.3	62.7
6	78.6	76.7	74.5	76.1	92.0	91.9	90.8	90.4	69.6	69.7	69.8	69.9	59.0	60.1	61.4	61.4
8	76.5	76.2	76.0	77.9	-	91.3	92.9	91.8	65.3	68.1	67.1	67.3	62.6	61.5	62.5	63.2
10	75.5	76.2	76.1	76.4	-	91.6	92.2	91.8	-	67.1	67.8	67.8	-	-	-	-

Table 5. Changes total sugar content of irradiated sprouting foods during storage (Unit : %)

Period (month) \ Dose (GY) \ Item	Potatoes 0	Potatoes 50	Potatoes 100	Potatoes 150	Onions 0	Onions 50	Onions 100	Onions 150	Garlic 0	Garlic 50	Garlic 100	Garlic 150	Chestnuts 0	Chestnuts 150	Chestnuts 200	Chestnuts 250
0	17.2	16.5	16.3	15.7	7.7	7.4	7.5	7.8	18.8	17.3	18.2	18.3	27.0	27.7	27.6	29.0
2	17.0	16.8	16.3	16.0	7.6	7.9	7.5	7.5	17.3	17.7	18.2	17.5	31.4	31.6	31.6	31.8
4	16.6	17.6	17.8	17.4	7.0	6.7	6.4	6.3	14.3	15.1	15.5	15.1	28.8	29.9	29.6	30.2
6	17.6	17.1	18.9	17.5	5.4	5.7	6.7	6.7	14.1	15.0	15.0	15.5	26.1	23.9	25.4	24.8
8	16.5	16.6	16.9	17.4	-	4.9	5.0	4.8	12.4	13.2	13.9	14.4	17.7	21.3	24.3	20.1
10	16.0	16.1	16.3	17.0	-	5.3	5.0	5.8	-	12.2	12.7	12.9	-	-	-	-

lts were almost in accord with the works of Pahissa et al[14] and Cho et al[3].

Changes in total sugar content during storage are shown in Table 5. In all stored groups, total sugar content gradually decreased according to the increase in dose and the length of the storage period, and after 8 months of storage the content was somewhat higher in the irradiated groups than in the nonirradiated ones in all samples.

Also, the reducing sugar content in the four stored samples was fructuated slightly during the storage period, and at the latter stage of storage, the content of the reducing sugar of potatoes and onions was lower in the irradiated groups than in the nonirrated ones (Table 6). Accordingly, it was evident that the irradiated potatoes, as material for chip processing, were superior to the nonirradiated ones because the color of potato chips is affected by the sugar content. There are many reports concerning the effect of irradiation on the physicochemical properties of the saccharrides,[17,19] and in general, it has been recognized that irradiation doses for sprout inhibition don't affect the chemical structure or content of sugar in foods.

As shown in Table 7, the ascorbic acid content of potatoes, onions and garlic were obviously decreased with the increase of irradiation dose and the length of storage period, while that of chest-

Table 6. Changes in reducing sugar content of irradiated sprouting foods during storage

(Unit : %)

Item / Dose (Gy) / Period (month)	Potatoes				Onions				Garlic				Chestnuts			
	0	50	100	150	0	50	100	150	0	50	100	150	0	150	200	250
0	0.26	0.36	0.15	0.11	5.39	4.20	3.84	4.72	1.00	0.93	0.93	0.92	0.35	0.49	0.60	0.67
2	0.25	0.30	0.21	0.18	4.27	4.19	4.27	4.68	0.88	0.93	0.70	0.73	2.01	1.51	1.93	2.09
4	0.24	0.28	0.28	0.24	5.40	4.83	6.66	6.45	1.07	1.05	1.11	1.11	1.16	0.94	0.80	0.88
6	0.18	0.14	0.11	0.14	3.54	3.50	3.89	3.87	0.95	1.92	0.88	0.85	0.49	0.52	1.25	1.32
8	0.47	0.20	0.56	0.56	-	4.46	3.70	2.94	0.96	0.77	0.95	0.83	1.42	1.57	1.87	1.98
10	0.64	0.42	0.45	0.44	-	2.84	2.92	3.37	-	1.25	1.27	1.27	-	-	-	-

Table 7. Changes in ascorbic acid content of irradiated sprouting foods during storage

(Unit : %)

Item / Dose (Gy) / Period (month)	Potatoes				Onions				Garlic				Chestnuts			
	0	50	100	150	0	50	100	150	0	50	100	150	0	150	200	250
0	24.5	22.1	22.6	22.0	7.2	6.8	6.8	6.7	10.8	10.8	10.8	10.6	20.0	17.9	22.4	23.4
2	22.6	20.9	21.7	19.7	6.2	6.2	6.7	6.5	10.8	9.6	9.3	8.7	19.1	20.1	24.0	22.1
4	19.4	18.6	19.7	15.3	6.1	6.3	6.2	5.4	9.4	9.4	9.3	8.6	22.4	22.0	24.6	25.6
6	18.8	17.7	17.8	14.9	5.9	6.3	6.6	6.1	8.6	8.8	9.2	10.0	23.5	24.2	25.0	24.8
8	12.1	9.6	8.5	9.6	-	6.3	6.2	6.3	9.4	9.2	9.0	8.3	24.6	21.7	22.3	23.7
10	12.3	11.6	12.7	11.7	-	5.9	6.3	6.0	-	10.4	10.4	8.4	-	-	-	-

nuts increased inversely. At 8 months after storage, the content of ascorbic acid of potatoes, onions and garlic was decreased up to 50.4 %, 18.8 % and 13.3 %, respectively in the nonirradiated groups and 60.6 to 65.3 %, 8.3 to 16.2 % and 14.9 to 23.5 %, respectively in the irradiated ones. In chestnuts, however, there was about a 17.5 % increase in the nonirradiated group and a 21 to 25 % increase in the irradiated group after 6 months of storage. Considering of the overall effects of gamma irradiation on ascorbic acid [11), it seemed that the above mentioned changes in ascorbic acid content might be based upon the influence of irradiation on the metabolism of sprouting foods itself and not on the chemical changes.

Similar results were obtained by other workers, [3,9,15) and it was suggested, especiavy, that the higher content of ascorbic acid at the latter period of storage must be closely related with the increase of the reducing sugar content during the same period in accordance with inter-conversion reactions.

요 약

저장상 많은 문제점을 내포하고 있는 감자, 양파, 마늘 및 밤의 장기 저장법 개발을 목적으로 수확후 1개월 이내에 Co-60 감마선을 조사하고 냉동기를 가동하지 않은 자연저온 저장고에 각각 저장하였다. 저장중 시료의 발아는 감자가 150Gy, 양파 및 마늘이 50Gy 밤이 250 Gy의 선량으로 8～10개월간 거의 완전히 억제되었다. 감마선 조사에 따라 부패율은 상당히 감소되었으며, 중량감소에 있어서도 적정선량의 조사는 네가지 시료에서 6～24 %의 감소 억제 효과를 나타내었다. 발아식품의 품질에 관여하는 성분인 수분, 당 및 비타민 C의 함량은 저장기간의 경과로 비조사구에 비해 조사구가 우수한 경향을 보였다. 따라서 이들 식품의 장기 안전저장을 위해서는 감자, 양파 및 마늘은 50 ～ 150 Gy, 밤은 250 Gy 정도의 감마선을 조사하고 자연저온저장고(10 ± 5℃, R. H. 75～85 %)에 저장하는 것이 효과적인 방법임을 시사하였다.

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