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Extension of Storage of Onions and Potatoes by Gamma Irradiation

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Abstract: Post-harvest management of onions and potatoes is a sever problem in Iran. In this regard a research project of radiation preservation of root crops was carried out. Ten tones of red variety of onions and pashandi variety of potatoes were used every year of the trial. Bulbs were irradiated at a dose of 0.10 kGy and stored along with the unirradiated controls, at low temperature and under ambient conditions for a period of more than 7 months. After 4 months of storage under ambient conditions, the rotting ranged from 1 to 15% in irradiated onions and 5 to 64% in unirradiated samples. The unirradiated potatoes were discarded after 6 months of storage, because of heavy sprouting and rotting. It was found that losses through dehydration were 9.4 to 14.9% in the irradiated potatoes. Also a comparative study of reducing and non-reducing sugars, vitamin-C contents, total sugar, starch and protein was carried out between control and irradiated samples. The percentage weight loss varied between 25 to 36% after 6 months of storage in the irradiated onions and 18 to 29% for untreated samples.

Key words: Preservation, gamma, irradiation, onions, potatoes, storage

Introduction

Onions and potatoes are vegetable crops of economic importance to Iran and are grown locally for domestic consumption. The annual production in the Northwest of country is approximately 300.000 and 200.000 tones, respectively. The crops are harvested once a year, from September to November. Thus, they have to be stored to ensure the supplies until the next harvest. The existing methods for long term storage are not adequate to control the deterioration, approximately 50% of the harvest is lost at few months of storage. Sprouting, weight loss and rotting are the major problems during storage. Extension of storage life and a reduction in post storage loss by radiation treatment would help to ensure a steadier supply and stabilize the prices (Olson, 1998 and Brynjolfsson, 1989).

Methods of storage have been designed to prolong the dormant period and to retard or inhibit the undesirable chemical changes (Wilkinson and Gould, 1996). Such methods involved classical low- temperature storage and the use of sprouting inhibiting chemicals such as malic hydroxide, α-naphthalene acetic acid, methylester, isopropyl n-3 phenyl carbonate and chloroisopropyl n-3 phenyl carbonate. Treatment with such chemicals, however, produce many undesirable side effects (McQeen, 1985).

Radiation has proved to be a useful tool for the extension of the shelf life of certain fruits and vegetables and food preservation. The results so far indicate promising possibilities. The critical problem, however, is to find the optimum radiation level that can fulfil the preservation requirements without causing serious chemical alteration of the food, which would affect its organoleptic acceptability and wholesomeness (Farkas, 1985).

Irradiation of onions and potatoes inhibits spouting and reduces the weight loss (Hayashi, 1988). Irradiation of onions on both the laboratory and commercial scale has been found to be economically feasible. In present study attempts have been made to ascertain the minimum radiation levels that can satisfactorily produce sprout inhibition in stored onions and potatoes, for this purpose the effect of gamma irradiation on onions and potatoes and its chemical changes has been investigated.

Materials and Methods

Collection of samples: Onions and potatoes grown in Bonab and Ajabshir in East Azarbijan Province, located in the Northwestern region of the country were used in the trials in 1996. Five tones of Red variety of onion and Pashandi variety of potato were taken to Nuclear Research Center in Tehran, simulating the normal marketing practice in Azarbijan. The bulbs and tubers were sorted for size and shape, and after curing only the sound samples were in jute bags (20-25 kg per bags).

Irradiation: A gamma source (^{60}Co) of Nuclear Research Center with strength of 500 curies and dose rate of 0.54 Gy/min was used for irradiation treatment. The average dose administered for onions and potatoes was 100Gy. Each bag was manually turned 180° during the total irradiation time. Fricke dosimeters were used to measure the absorbed dose during irradiation.

Storage: The irradiated and non-irradiated onions and potatoes were stored in ordinary storage at Atomic Energy Organization of Iran, under ambient conditions at temperature (3.5-26.5°C) and relative humidity (28-92%). The period of storage was September-April 1996. The temperature and relative humidity during these months are varied considerably because this period includes both summer and winter months.

Quality evaluation: The onions and potatoes were inspected monthly for sprouting, softening, rotting, weight loss and percentage of good bulbs and tubers. Quality inspection of the onions and potatoes during post-storage at ambient temperature was also done periodically until the commodities reached a total of more than fifty percent storage defects. The bulbs and tubers in the case of control and irradiated were examined periodically for changes in reducing and non-reducing sugar, ascorbic acid, total sugar, starch and protein content. Thin layer chromatographic studies of sample extracts and spectrophotometric analysis of the components of onion and potato extracts obtained from preparative thin layer plates were followed according to the method described by Pearson (1976). Separation of the components was achieved using petroleumether and diethylether. Spectrophotometric data were obtained from Beckman D.B. Spectrophotometer. Reducing and non-reducing sugars were estimated by Joslyn method (Joslyn, 1970). For the estimation of ascorbic acid, the plant material was macerated in a metaphosphoric acid solution. Thereafter, the filtered solution was titrated against a standard solution of sodium salt 2:6 dichlorophenol indophenol (Horwitz, 1975).

Results and Discussion

Storage tests: The percentage sprouting, softening, decay and weight loss in irradiated and control bulbs stored up to 8 months in ambient conditions storage is shown in Tables 1,2 and 3. The results show that after 5 months of storage only 30% good bulbs were recovered from the irradiated lots, respectively.

The length of dormant state of red onions appeared to be about 2 weeks following the harvest. The results obtained by this study indicated that complete sprout inhibition with a dose about 100Gy during 7 months storage. The dormancy period could be extended by low temperature storage of onions after harvest.

Another reason to recommend the irradiation treatment of onion bulbs at an early stage of post harvest storage is to minimize the amount of discoloration at inner buds which causes darkening during post irradiation storage (Takano and Aoki, 1974).

Losses due to sprouting were effectively controlled in irradiated samples, also rotting after storage time was 64% in control samples compared with 15% irradiated bulbs (Table 2).

Weight loss was also reduced by irradiation treatment, after 7 months of storage, the weight loss ranged from 46 to 48% in the control samples and for irradiated one was found to vary between 28-30% (Table 3).

Nuttall and Lyall (1971) reported that no significant differences in weight loss were found between unsprouted control and bulb irradiation with doses ranging from 32 to 95 Gy. In the Canadian experiment, total weight loss of onion bulbs irradiated with 68 and 85 Gy was 5.7% as against 23.2% for unirradiated bulbs after 5 months storage (AEC, 1972). With onion bulbs, Umeda *et al.* (1979) observed no consistent effect of irradiation at the dose levels of sprout inhibition on the development of storage rot.

During storage, tubers and bulbs are exposed to a risk of infection by harmful microorganisms leading to the development of rotting and decay such as wet rot, dry rot and concomitant creamy decay. Although no significant incidence of storage rot in irradiated tubers and bulbs is reported in some studies. For long-term storage of tubers and bulbs, rotting may become a serious problem (Kim *et al.*, 1970).

The results of studies on the percentage of marketable tubers, sprouting rotting and weight loss in irradiated and non-irradiated potatoes are summarized in Tables 4 to 6. The Tables show that irradiation effectively controlled sprouting and caused weight loss.

Many studies have indicated that irradiation during the dormancy period of tubers and bulbs is the most effective for sprout control (Thayer *et al.*, 1993a; Thayer and Boyd, 1993b and Huhtanen, 1990). The length of the dormancy period of potatoes is affected little by storage temperature, but it is significantly dependent upon their variety. Pashandi variety has a dormancy period of about 45 days.

Non-irradiated tubers stored for more than 6 months had a higher percentage weight loss and rotting. The rot attack was approximately double in unirradiated samples after a storage period of 6 months.

Curing the potato tubers before irradiation can reduce rotting during subsequent storage, because cutting will allow the tubers a chance to heal harvest wounds. The healing ability of tubers is reduced by irradiation.

Exhalation of chemical qualities: Changes in percentage of reducing and non-reducing sugars, total sugar, Vitamin C and protein content in onion bulbs and potato tubers are shown in Tables 7 to 10. In case of control onions the content of both reducing and non-reducing sugars decrease during storage. Whereas in irradiated onions the content of reducing sugar increased till the end of the storage time.

Table 1: Effect of irradiation on the sprouting of onion bulbs

Treatment	Sprouting (%)							
	Storage time (months)							
	1	2	3	4	5	6	7	8
Irr.	0	0	12	17	38	45	51	59
Non-Irr.	0	9	17	36	70	85	91	100

Table 2: Effect of irradiation on the rotting of onions bulbs

Treatment	Sprouting (%)							
	Storage time (months)							
	1	2	3	4	5	6	7	8
Irr.	0	0	1	1	7	7	10	15
Non-Irr.	0	0	0	5	8	19	32	64

Table 3: Effect of iradiation on the percentage weight loss of onions

Treatment	Weight loss (%)							
	Storage time (months)							
	1	2	3	4	5	6	7	8
Irr.	0	3	3.5	9	14	18	24	29
Non-Irr.	0	3	3.0	15	21	25	36	47

Table 4: Effect of irradiation on the sprouting of potato tubers

Treatment	Sprouting (%)							
	Storage time (months)							
	1	2	3	4	5	6	7	8
Irr.	0	0	0	5	10	23	30	38
Non-Irr.	0	9	0	45	80	90	100	100

Table 5: Effect of irradiation on the percentage weight loss in potato tubers

Treatment	Weight loss (%)							
	Storage time (months)							
	1	2	3	4	5	6	7	8
Irr.	0	1.3	3.2	4	4.5	6.5	9.4	14.9
Non-Irr.	0	1	3.6	5.2	7	11.1	17.2	26.8

Table 6: Effect of irradiation on the rotting of potato tubers

Treatment	Rotting (%)							
	Storage time (months)							
	1	2	3	4	5	6	7	8
Irr.	0	0	0	0	3	9	14	23
Non-Irr.	0	0	0	1	1	4	8	12

Table 7: Changes in percentage of reducing sugars in onions and potatoes

Storage period (months)	Reducing sugars (g/100g)			
	Onions		Potatoes	
	Irr.	Non-Irr.	Irr.	Non-Irr.
1	3.92	3.69	0.188	0.095
2	3.24	3.41	0.286	0.129
3	3.18	3.38	0.380	0.232
4	3.57	3.55	0.286	0.104
5	3.56	3.72	0.165	0.280
6	3.36	3.15	0.130	0.216
7	3.13	2.80	0.080	0.196
8	2.20	2.02	0.153	0.210

Table 8: Changes in percentage of total sugar in onions and potatoes

Storage period (months)	Total sugars (g/100g)			
	Onions		Potatoes	
	Irr.	Non-Irr.	Irr.	Non-Irr.
1	4.96	5.05	0.712	0.240
2	4.80	5.20	0.848	0.320
3	4.72	4.96	1.152	0.576
4	4.68	5.04	0.896	0.432
5	5.04	5.20	0.592	9.736
6	5.00	4.84	0.530	0.554
7	4.96	4.24	0.432	0.448
8	4.89	3.76	0.668	0.464

Table 9: Changes in percentage of starch in potatoes

Storage period (months)	Starch (g/100g)	
	Irr.	Non-Irr.
1	11.66	11.80
2	10.65	11.16
3	10.44	11.52
4	8.82	8.82
5	9.52	9.27
6	8.35	9.54
7	8.32	9.22
8	8.36	9.16

Table 10: Changes in percentage of Vitamin-C in onions and potatoes

Storage period (months)	Vitamin-C (mg/100g)			
	Onions		Potatoes	
	Irr.	Non-Irr.	Irr.	Non-Irr.
1	20.0	22.4	6.6	8.0
2	18.7	21.0	5.6	7.3
3	16.5	18.6	4.8	6.4
4	12.0	15.2	4.4	5.7
5	8.0	10.5	3.3	4.7
6	8.1	10.4	3.4	4.6
7	8.2	10.5	3.5	4.1
8	8.3	9.7	3.2	3.7

Table 11: Changes in percentage of protein content in onion and potatoes

Storage period (months)	Protein content (g/100g)			
	Onions		Potatoes	
	Irr.	Non-Irr.	Irr.	Non-Irr.
1	2.02	2.04	2.90	2.45
2	2.01	2.17	3.11	2.29
3	1.75	1.83	2.63	2.39
4	1.93	1.95	2.81	2.30
5	2.14	2.25	2.85	2.11
6	1.90	2.00	2.90	2.30
7	1.57	1.58	3.05	2.78
8	1.60	1.63	3.05	2.77

The higher sugar content of irradiated tubers was observed after storage at low temperature as compared with storage at higher temperature, which is the disadvantage for processing of potato tubers (Ogawa and Hyodo, 1989).

Irradiation of potatoes with sprout-inhibiting doses do not change carbohydrate content. Varietal differences only were significant for starch content in a dose range up to 15Gy throughout the storage period of 8 months at 4.5 and 20°C (Table 9). It appeared that the storage temperature had a much greater effect on total sugar, reducing sugars, and starch contents than the effect of irradiation with doses up to 40Gy (Schreiber and Highlands, 1978).

Although the conversion of reducing sugars to starch took place by reconditioning, there was no significant effect on starch content of potatoes owing to reconditioning. Many studies showed that irradiation induces the increase in total and reducing sugar contents. Increase in sugar content is disadvantageous, especially for processing, because of sweetening on cooking and discoloration of crisps (Ussuf and Nair, 1972). At storage temperatures below 5 °C, starch in rubbers is converted into sugars whereas at storage temperatures above 10 °C, sugars are transformed into starch. With onions, no significant difference in the total sugar and reducing sugar contents was found between irradiated and unirradiated bulbs in a dose range of 30 to 100 Gy (Dallyn and Sawyer, 1979). There was a reduction in ascorbic acid content of onions as a result of irradiation (Table 10).

Rubin and Metlisky (1978) observed irreversible oxidation and decomposition of a considerable part of ascorbic acid in tubers during first 2 or 3 hours following the irradiation. After the initial loss of ascorbic acid and starch, differences between irradiated (100Gy) and unirradiated tubers in the content of ascorbic acid and starch diminished, and the contents of the control fell more rapidly and to a greater extent than those of irradiated tubers as the control tubers emerged from the dormancy state (Rubin and Metlitsky, 1978).

With onion bulbs, the ascorbic acid content appeared not to be significantly affected by irradiation (Iwata and Ogata, 1989). Chachinki *et al.* (1972) noted that reduction in effectiveness of sprout inhibition by delayed irradiation of bulbs may result from the increase in ascorbic acid and other reducing compounds which are in the inner buds at the time of emergence from the dormancy state.

The date with regard to changes in percentage of protein content in onions and potatoes are presented in Table 11.

There were some changes in the concentration of proteins in potato tubers (FAO *et al.*, 1977). The results obtained indicated that the rate of change of potato protein was very slow and partly of some order as that observed during boiling (Fuzimaki and Tazima, 1978). No significant difference in the concentration of protein bound amino acids was found between unirradiated and irradiated tubers. Changes in biological value and net protein ulilization of potatoes were not induced by irradiation (Varela and Urbano, 1971).

It was established that irradiation of onions and potatoes at 100Gy and storage under ambient conditions could extend the storage life of these vegetables for more than 6 months under Iran conditions.

In general, it is known that the application of appropriate low doses to tubers and bulbs can be expected to result in excellent sprout control, although too great a dosage induces unfavorable side effects. From developmental studies conducted in many countries, doses between 50 and 150 Gy preferably a dose range from 60 to 120 Gy are recommended for sprout control of tubers and bulbs in dormant state shortly after harvest (IAEA, 1982).

It has been recommended that irradiated potatoes, be stored at 12 °C because of weight loss from storage and sprouting at this temperature. In the control tubers the weight loss due to shrinkage increased from 4 to 34% during 5 months following the sprout development (Truelsen, 1980). Sawyer and Dallyn (1981) showed a similar reduction in weight losses in four varieties of irradiated potatoes during storage at 10°C due to sprouting and shrinkage after exposure to 50-150Gy, when compared with non irradiated control potatoes (Sawyer and Dallyn, 1981).

The smaller size of onion bulbs gave lower incidence of rotting and a higher percentage of sound bulbs. Smaller bulbs sprout faster than larger ones of the same variety (Sawyer and Dallyn, 1981).

Irradiation should be practiced during the dormancy period of tubers and bulbs to minimize the necessary dose. Good ventilation and the use of pallet boxes as containers for tubers offer advantages in storages and handling Post-irradiation storage of onion bulbs at low temperature is recommended, when discoloration of growth centers must be suppressed. High humidity in the storage room appears to be largely responsible for rotting (Warland and McQeen, 1986).

Immediately after irradiation, potato tubers display a transient increase in the contents of both reducing and non-reducing sugars. The study observed a significant degree of sweetness in irradiated potatoes.

Burton and Horne (1979) indicated that potatoes irradiated with 100 Gy and stored at 10 ºC, have increased the content of non-reducing sugars, up to a maximum of rather more than 1 Gy/100g, reached after about 5 days followed by a rapid decrease down to the control level, about 26 days after irradiation. This temporary rise in non-reducing sugar content immediately after irradiation was independent of the date of irradiation and depend upon the radiation dose (Burton and Horne, 1979). On the other hand, unirradiated tubers increased the sugar contents after the long period of storage at 10 ºC in comparison with irradiated tubers (Hashisaka, 1990).

Cloutier and Cox (1989) observed that contents of reducing sugars and sucrose in irradiated tubers showed an initial rise, followed by a decrease down the control level after storage of 4.5 months at 4.5 ºC, and that the sucrose content in the treated tubers largely increased after 8 months of storage at 20 ºC (Cloutier and Cox, 1989). Irradiation of potato tubers caused some slight loss of ascorbic acid not exceeding 15% at sprout-inhibiting dose. Since its loss during subsequent storage was comparatively large, no significant difference in ascorbic acid content between unirradiated and irradiated potatoes was found after proloped storage (Ogata and Tatsumi, 1983).

As mentioned above, the irradiation process for sprout inhibition of potatoes and onions is now coming to the stage of commercialization and many countries are conducting their own projects to bring this application to realization. However, it should be recognized that there are several fundamental problems which must be solved in each country and region to make sure the success of project as a whole.

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