

Potato Sprout Inhibition and Tuber Quality after Post Harvest Treatment with Gamma Irradiation on Different Dates

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ABSTRACT

Storage of potatoes is very important because fresh potatoes are available only for a few months in a year. Thus, any treatment such as irradiation that controls sprout growth and extends shelf life of potatoes could be beneficial. In this study, potato sprout inhibition and tuber quality after treatment with various levels of Gamma Irradiation (0, 50, 100 and 150 Gy) on different dates (10, 30 and 50 days after harvest) were studied during prolonged storage at 8 and 16°C using tubers of Agria variety. A factorial experiment based on a randomized split plot design with three replications was carried out. There was minimum sprout development (4.83 ± 0.01 g/3kg tuber) in tubers from early irradiation date (10 days after harvest). This study indicated that early irradiation and higher irradiation levels significantly decreased sprouting, percent weight loss and specific gravity of tubers. The loss of ascorbic acid and the contents of reducing and non-reducing sugars significantly increased by delay in irradiation whereas the content of sugars and ascorbic acid level decreased by irradiation. The loss of firmness became clearer during five months storage in non-irradiated tubers. Higher storage temperature (16°C) caused greater loss of ascorbic acid (20.34%). In other words, tubers stored at 16°C showed greater metabolic changes as indicated by sprouting, weight loss, and changes in sugars and ascorbic acid contents. The 50 Gy irradiation treatment on the 10th day after harvest resulted in complete sprout inhibition of tubers at 8°C storage and 150 Gy dose while inhibiting sprouting at 16°C, caused greater loss of ascorbic acid. Tubers irradiated with later after harvest were subject to greater loss of ascorbic acid in response to higher doses of irradiation and higher storage temperature. Consequently, to reduce undesirable changes in Agria potato tubers, delay in irradiation and storage at high temperature are not recommended.

Key words: Different Dates, γ -Irradiation, Potato, Sprouting, Storage

INTRODUCTION

The annual farming land of potatoes in Iran is about 180000 hectares. Iran is the world's No. 10 potato producer and the third biggest in Asia, after China and India. In 2007, the country's farmers achieved an all-time record harvest of 4.5 million tones, with per hectare yields averaging 25 tones.

Potatoes are a vegetable crop of economic importance to Iran and are grown locally for domestic consumption. The crops are harvested once a year from September to November thus they have to be stored to ensure supplies until the next harvest (FAO, 2007). Potato is a highly nutritious, mild flavored, easy to blend food that has possibilities for "building in" desired nutrients (Arvanitoyannis et al., 2008). The

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currently applied methods for long term storage are not adequate to control the deterioration as approximately 50% of the product is lost in a few months of storage. Sprouting, weight loss, rotting and low temperature sweetening 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 (Brynjolfsson, 1989; Brierley et al., 1996; Olson, 1998).

Factors contributing to qualitative and quantitative deterioration of the potato could be grouped into four categories including physical, physiological, microbiological, and entomological factors. Methods of storage have been designed to prolong the dormant period and to retard or inhibit undesirable chemical changes (Wilkinson and Gould, 1996). Such methods involve classical low-temperature storage and the use of sprouting inhibiting chemicals such as maleic hydroxide, α -naphthalene acetic acid, methylester, isopropyl N-(3chlorophenyl) carbonate and 1, 2, 4, 5 tetra chloro-3nitro benzene. Treatment with such chemicals however, produces many undesirable side effects (McQueen, 1985). In fact, the use of mechanical refrigeration for low-temperature storage is limited by economics and the use of chemical sprout inhibitors by food safety regulations. On the other hand, low-temperature storage induces sweetening in potatoes (Ogava and Hydoo, 1989) due to increase in high reducing and total sugars thereby making them unsuitable for chips-making (Kumer et al., 2007). Application of Gamma irradiation is a well-known method to eliminate or inactivate the spoilage causes with no adverse effects on nutritional and sensory quality of foods. Gamma irradiation use is gradually increasing worldwide (WHO, 1999; Bidawid et al., 2000). However, irradiation induced softening has been reported for a number of fruits and vegetables by many researches (Prakash et al., 2002; Kovacs et al., 1997; Rastogi and Raghavarao, 2004; Rastogi, 2005). Also Joshi et al. (1990) showed that potatoes

irradiated with 100 Gy and stored at 15°C for 6 months had lower sugar levels than control tubers stored at 2-4°C and the suitability of tubers for processing into crisps and French fries was not affected by irradiation and storage at 15°C for 6 months. Also, Hayashi (1988) indicated that irradiation on potato tubers inhibited sprouting and reduced the weight loss. Therefore, the application of irradiation may be an alternative treatment for controlling undesirable changes in potatoes during long-term storage.

Appropriate use of irradiation can extend shelf life, reduce the requirement of chemicals for preservation and pest control, produce sterilized products (controlling the microorganisms) that can be stored without refrigeration, delay the ripening of fruits and vegetables and limit quality deterioration of stored tuber and bulb crops by preventing postharvest sprouting (Wierbicki, 1986; Arvanitoyannis et al., 2009). The critical problem, however, is to find the optimum radiation level that can fulfill the preservation requirements without causing serious chemical alterations in the food, which would affect its organic acceptability and wholesomeness (Farkas, 1985). As Frazier (2006) showed, successful sprout suppression was achieved with doses of 40 to 50 Gy while higher doses caused undesirable increases in reducing sugars in the tubers. From developmental studies conducted in many countries, doses between 50 and 150 Gy are recommended for sprout control of tubers and in dormant state shortly after harvest (IAEA, 1982; Majd and Ardakani, 2003). Many studies have indicated that irradiation during the dormancy period of tubers is the most effective for sprout control (Thomas, 1984; Luther et al., 1990; Singh et al., 2009). The length of the dormancy period of potatoes is slightly affected by storage temperature, but it is significantly dependent upon their variety. Agria variety has a dormancy period of about 50 days (Afshari, 2006). The results of many of these studies are not comparable because of the differences in materials used

and storage conditions (Golachowski, 1985) and optimization of this technology for its utilization in every region is needed. In this study, the effects of low dose gamma irradiation (50, 100 and 150 Gy) with different delays (10, 30 and 50 days) after harvest on sprouting and physical and nutritional changes of Agria potato tubers were determined during 5 months storage at 8 and 16°C.

MATERIALS AND METHODS

Growth and storage of potato tubers

This research was conducted to investigate interactions of irradiation, time of irradiation and temperature levels. Agria potato tubers were planted on April 25, 2008 and fertilized with 220 kg/ha in 16-16-16 NPK mixed fertilizer in Damavand area. The plants were tilled two times and irrigated five times along the vegetation period. Tubers were harvested in mid October 2008, washed, dried and graded for average size (150-200 grams) tubers and transferred to the Nuclear Research Center in Karaj on the same day. Manageable quantities of approximately 3kg for each sample were placed in aerated plastic string bags and stored at 8°C with 90% relative humidity for 10 days.

A 10-tubers sub sample was selected at random for quality analysis. Samples were exposed to 50, 100 and 150 Gy irradiation 10, 30 and 50 days after harvest. The dose rate at the time of irradiation was 2183 rad/min. Each sample was placed in an iron basket and exposed to irradiation (cobalt-60) for different periods of time. The time limit for irradiation was 2min. 18s, 4min.36s and 6min.54s for 50Gy, 100Gy and 150Gy, respectively. After irradiation, the 3Kg plots were randomly divided with 1/2 of the tubers stored at 8°C and the other at 16°C with 85 to 90% relative humidity. Tubers were stored for five months.

The design of the experiment was a split-split plot with three replications with a total of 18 treatments in each replicate. Dates of Irradiation were assigned to the main plot, irradiation levels to the first split and temperatures to the second split plot. Analysis of variance and statistics were done using SAS.

Quality Evaluation

Sprout weight and weight loss

Samples were removed from storage room at the termination of the storage period and the sprouts from the sprouted tubers were removed, weighed (SE= ±0.01g) and expressed in g/3kg of tubers. Final tuber weight (tuber weight after storage minus sprouts) was subtracted from the initial weight prior to storage to determine weight loss (Mehta and Kaul, 1991; Nouri and Toofanian 2001)

Specific Gravity

The following formula was used for determining the specific gravity (Freeman et al., 1998)

$$\text{Specific gravity} = \frac{\text{Weight in air}}{(\text{Weight in air} - \text{Weight in water})}$$

The means of five measurements were reported as specific gravity for each observation. Specific gravity was determined prior to irradiation and after irradiation and storage. Differences were converted into percentages of original specific gravity.

Sugar Analysis

Total soluble carbohydrates and reducing sugars were determined before irradiation and immediately after the termination of storage period. The procedure was that outlined by Iritani et al. (1973), Shekhar et al. (1978), Knowels (1983) and Revathy et al. (2007). Six lengthwise wedge pieces



from the tubers were blended for 30 seconds in a waring blender to which a few grains of sodium bisulfate (NaHSO_3) were added to prevent browning. The mixture was stirred and 50 ml of 50% ethanol in a beaker was added to a 20 g aliquot of the sample, and allowed to settle on shredded ice until ready to use. Soluble reducing sugars were determined by the dinitrophenol colorimetric method. Intensity of color was read at 600 nm on a Bausch and Lomb spectrophotometer (Spectronic 21). Standards containing 0-0.4 mg/ml dextrose were used with the samples. The remaining 20 g aliquots were placed in an oven at 70°C for 48 hours to determine percent dry matter. Total sugar was determined by hydrolysis of a 10 μl aliquot with concentrated sulfuric acid and 5% phenol. Intensity of color was read at 485 nm on a spectrophotometer. Standards containing 0-40 μl dextrose were used for the assay. Difference between total sugar and reducing sugars was considered non-reducing sugar. All sugar contents were expressed on a dry weight basis and the differences between preirradiation and postirradiation storage were calculated on a percentage basis of preirradiation weight.

Ascorbic Acid Determination

Method of enzymatic analysis was used for the estimation of ascorbic acid content (Hughes et al., 1971; Beutler and Beinstingl, 1980). The ascorbic acid enzymatic analysis kit was obtained from Boehringer Mannheim Biochemicals (product #409677) Indianapolis, Indiana and the procedure was followed as per instruction manual (Instructions for the analysis of food stuffs, methods of enzymatic analysis). One gram of lyophilized potato tuber tissue ground to 40 mesh was extracted in 40 ml of redistilled water in a 50 ml volumetric flask to which was added 5 ml of metaphosphoric acid (15% w/v) and 0.1 ml of n-octanol and was thoroughly mixed. The pH was adjusted to 3.4-4 with potassium hydroxide (2mol/l) and was controlled using a pH meter (model 701/ Digital Ionalyzer).

The final volume was brought to 50 ml with redistilled water and filtered through a Whatman No.1 filter paper. The filtrate was used for analysis according to the procedure outlined in the instruction manual. Optical density readings at 578 nm were recorded in triplicate for each sample on a spectrophotometer (Bausch and Lomb Spectronic 21) and total ascorbic acid content was determined. The difference in ascorbic acid was calculated and expressed on percentage basis of prestorage content.

Measurement of Firmness

Firmness was measured as Kg with 0.79 cm probe of Ft327 brand penetrometer (Effegi, Alfonsine, Italy, $\text{SE}=\pm 0.1\text{kg}$). Measurements were performed as a single reading in the middle part of the tuber. The means of five measurements were reported.

RESULTS AND DISCUSSION

Sprout Weight

Sprout weight differed significantly in terms of irradiation date, irradiation and temperature levels in this study (Figure 1). Later irradiation exposures caused a significant ($p<0.05$) increase in degree of sprouting (11.95 ± 0.01 g/3kg tuber) because late irradiation results in some potatoes coming out of dormancy period. There was minimum sprout development (4.83 ± 0.01 g) in tubers from early irradiation date (10 days after harvest). Increasing irradiation significantly ($p<0.01$) reduced sprouting. The 150 Gy irradiation dose completely prevented sprouting at both temperatures studied. Irradiation generally reduced sprouting at a low dose and at high temperature storage (16°C). The 50 Gy irradiation dose completely inhibited sprouting at low storage temperature. Irradiation at 50, 100 and 150 Gy levels completely inhibited sprouting at 8°C in tubers from all three irradiation dates. The 50 and 100 Gy doses

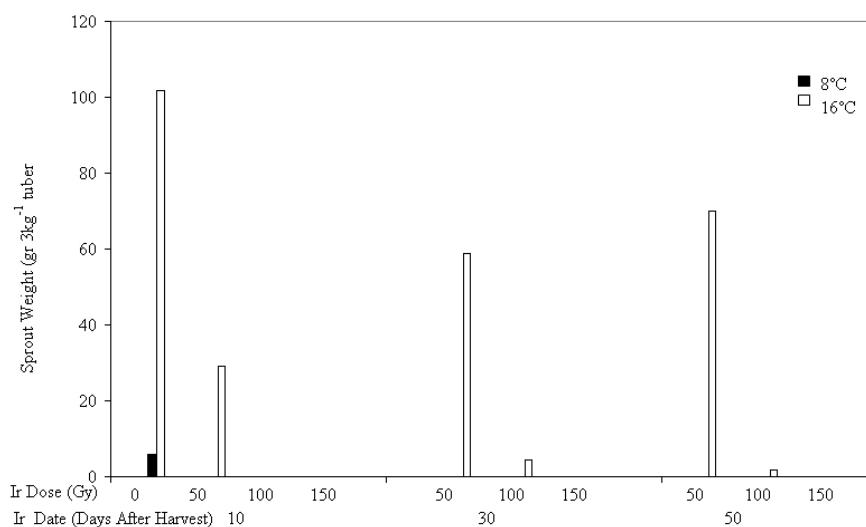


Figure 1. Irradiation effects on sprout weight ($\text{gr } 3\text{kg}^{-1}$ tuber) of Agria potato tubers that irradiated in different dates and stored for five months at 8 and 16°C.

partially inhibited sprouting at 16°C storage temperature in tubers irradiated on the 50th and 30th days after harvest however a gradual increase in sprout weight was observed with increasing delay in irradiation. Tubers immediately after harvest are in a metabolic state and are more sensitive to irradiation (IAEA, 1982), which can disrupt nucleic acid, nucleotide and hormonal synthesizing system, (Josephson and Peterson, 1983) and therefore fail to sprout.

Temperature as a major factor in controlling sprouting in tubers also altered the irradiation response. Low temperature storage significantly ($p < 0.01$) reduced sprouting (0.58 ± 0.01 g/kg) as compared to the higher storage temperature which caused 26.5 g of sprouts. Low temperature (8°C) storage was better for 50 Gy irradiated tubers as compared to untreated control.

Tubers to be stored at higher temperature (16°C) need higher irradiation dosage. All interactions were significant which showed that earlier irradiation had the least sprout growth. Storage temperature after irradiation reduced the effect of sprout inhibition, thereby indicating that higher temperature storage needs higher irradiation dosage. The sprouting of tubers irradiated on 30th and 50th days after harvest takes place only after the nucleic acids are accumulated in the growing points to a

definite level of content and composition (Matsuyama and Umeda, 1983; Josephson and Peterson, 1983).

All the non-irradiated tubers stored at 8 and 16°C and the 50 Gy irradiated tubers irradiated on the 30th and 50th days after harvest and stored at 16°C were not suitable for fresh market being soft and shriveled due to sprouting. The sprout inhibition effect of irradiation may be the basis for physical and biochemical changes in tubers during storage. Irradiation on all three dates reduced sprouting in tubers. Lower storage temperature played an important role in reducing sprouting of tubers.

Weight Loss

In this study, date of irradiation, irradiation and temperature levels all significantly affected potato weight loss (Figure 2). Irradiation levels significantly ($p < 0.01$) decreased weight loss while higher temperature significantly ($p < 0.01$) increased it. Irradiation at doses 100 and 150 Gy decreased weight loss 5.5 and 5.3 %, respectively at both temperatures. Weight loss differed significantly among irradiation dates as tubers irradiated on the 10th day after harvest lost more weight (6.6%) at both temperatures as compared to other dates. This may be due to a

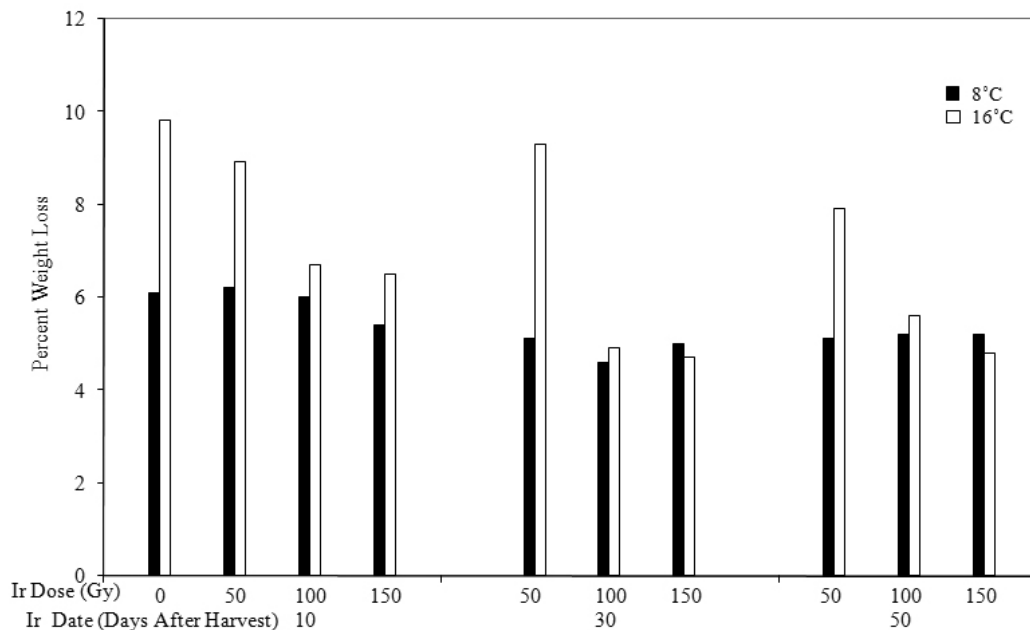


Figure 2. Irradiation effects on percent weight loss of Agria potato tubers irradiated in different dates and stored for five months at 8 and 16°C.

delay in wound healing and a change in the membrane function of the irradiated tubers which increase permeability causing higher respiration (Takano et al., 1974; Chachin and Iwata, 1981).

The greater weight loss (6.9%) at 16°C may be due to higher respiration rate, increased membrane permeability (Chachin and Iwata, 1981), and more sprout development (Figure 1).

Weight loss decreased with increasing irradiation dosages as was found by Sparks and Iritani (1964). Non-irradiated tubers showed a significant increase in weight loss (9.8%) at the higher temperature level (16°C), which decreased with increasing dose of irradiation and reached the same level (5.2 and 5.3%) at 8 and 16°C storage temperature except in tubers irradiated immediately after harvest.

Storage of irradiated tubers at 8°C was better than storage at 16°C also for non-irradiated tubers (Figure 2). The difference in weight loss due to temperature decreased with increasing dosage of irradiation which showed that higher storage temperature required higher dosage of irradiation (Umeda et al., 1969). Therefore, storage of tubers is possible at higher

temperature (16°C) if irradiated with higher dosages (100-150 Gy).

Irradiation in combination with early date of irradiation significantly decreased weight loss but interaction of irradiation date and temperature levels had no significant effect.

Specific Gravity

In this study, an overall increase in the specific gravity of tubers after five month storage was observed. The change in specific gravity was significantly less in tubers from earlier irradiation and higher irradiation levels than the other tubers but was increased by higher temperature levels (Figure 3). Tubers irradiated on the 50th day after harvest showed the greatest change (0.36% increase) in specific gravity followed by tubers from the earliest date of irradiation. The least change (0.06%) was observed in the tubers irradiated on the 30th day after harvest. Tubers irradiated on the 50th day after harvest resulted in less change of specific gravity as compared to non-irradiated tubers. Irradiated tubers stored at 16°C resulted in greater changes (0.27% increase) of specific gravity as compared to

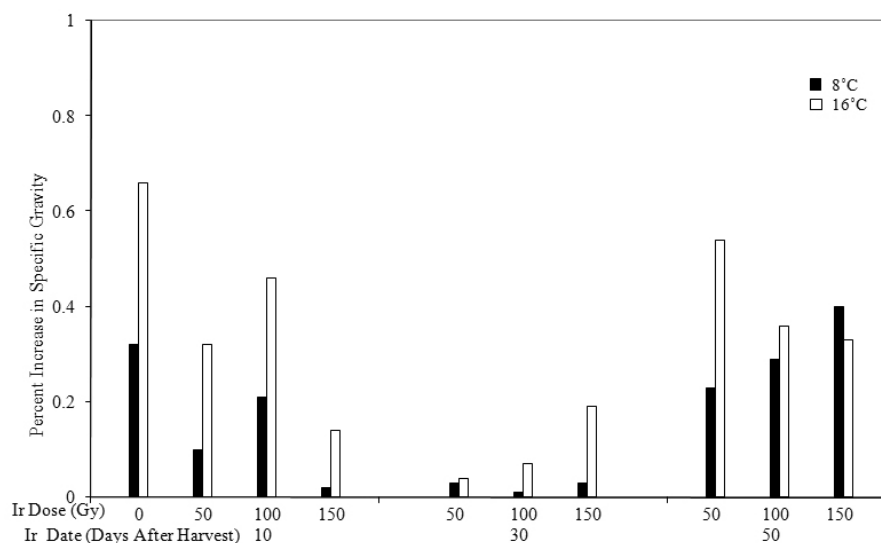


Figure 3. Irradiation effects on percent increase in Specific Gravity of Agria potato tubers irradiated in different dates and stored for five months at 8 and 16°C .

low temperature (8°C) storage but still had less change than the untreated control (Figure 3).

Sugars Metabolism

Results of sugar metabolism are given in Figures 4 and 5. Initial value for reducing

sugars of Agria tubers was zero. Irradiation date and irradiation levels significantly reduced reducing sugars (Figure 4) in comparison to the control (no irradiation) tubers. Tubers irradiated on the 50th day after harvest accumulated significantly more reducing sugars (1.4%), which were lower (0.72%) in tubers irradiated on the 10th day after harvest indicating the effects of

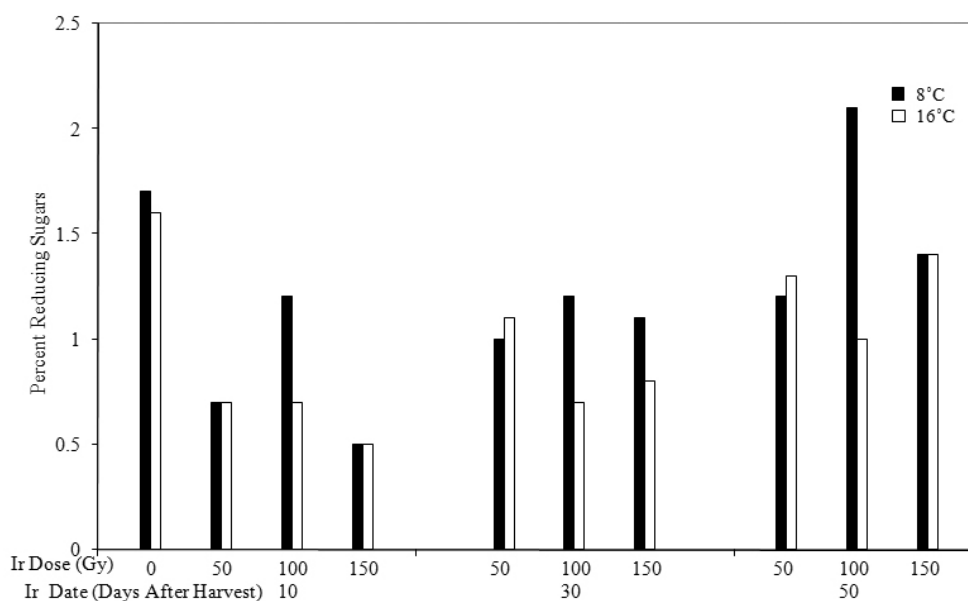


Figure 4. Irradiation effects on percent reducing sugars content of Agria potato tubers irradiated in different dates and stored for five months at 8 and 16°C .

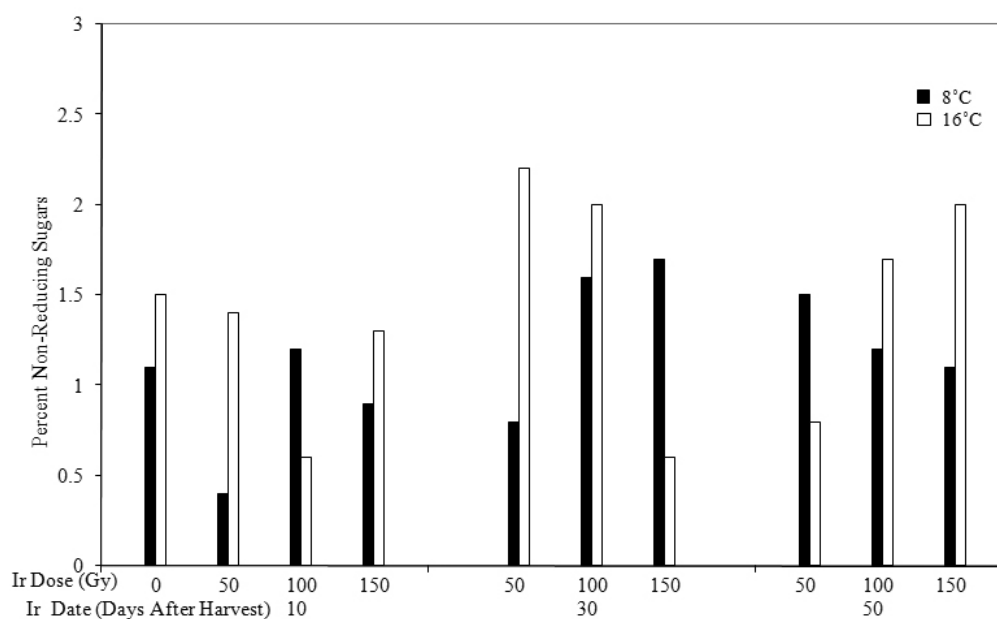


Figure 5. Irradiation effects on percent Non-reducing sugar content of Agria potato tubers irradiated in different dates and stored for five months at 8 and 16°C .

physiological aging so that the later the date of irradiation, the greater the increase in reducing sugars. Irradiated tubers had lower reducing sugar contents as compared to the untreated control (Fiszer et al., 1985; Thomas, 1984; Joshi et al. 1990; Gökman et al., 2007). With irradiation on the 10th day after harvest there was a gradual decrease in reducing sugars with increasing irradiation dose as was found in the work of Ussaf and Nair (1972).

Tubers irradiated at 100Gy dose and stored at 8°C developed more reducing sugars than those stored at 16°C (Figure 4). This may be due to utilization of reducing sugars as substrate for respiration at higher temperature because there is an increase in respiration at higher temperatures. These findings agree with those reported by Burton et al. (1959 a, b). The non-irradiated tubers were sprouted and hence may have utilized the excess sugars for energy production during sprouting and for higher respiration rate.

Initial value for non-reducing sugar of Agria tubers was 1.53%. Irradiation date and irradiation significantly affected the changes in non-reducing sugars. Tubers irradiated on

the 30th and 50th days after harvest behaved differently than those irradiated on the 10th day after harvest in response to irradiation and temperature levels. Maximum decrease of non-reducing sugars (38.8%) was found in tubers irradiated on the 10th day after harvest. Higher doses of irradiation (100 and 150 Gy) caused less decrease (4.89 and 15.51%, respectively) as compared to non-irradiation and 50 Gy irradiation which caused 32.45 and 24.46% decreases, respectively (Badshah et al., 1990).

Interaction of irradiation date with irradiation and temperature further decreased non-reducing sugars. Irradiation decreased non-reducing sugars by 14.9 %. An increase in reducing sugars (Figure 4) and a general decrease in non-reducing sugars showed some relationship. These results are contrary to those of Hayashi and Asoka (1985), Hayashi and Kawashima (1982) and Schwimmer et al. (1957) who applied very high irradiation dosages such as 300-400 Gy to potato tubers and stored these for shorter periods of time, which may have activated sucrose synthesis through increase in enzymes and reduced the synthesis of reducing sugars. The decreased levels of

sugars in irradiated tubers are important both for satisfactory color and lower acrylamide contents in fried potato products (Gökman et al., 2007).

Ascorbic Acid Metabolism

There is usually a decrease of ascorbic acid content in potato tubers during storage as reported in the findings of Yamaguchi et al. (1960), Sweeny et al. (1969), and Shekhar et al. (1978), Kameyama and Ito (2000), and Nouri and Toofanian (2001). Percents of ascorbic acid loss in irradiated potatoes are presented in Figure 6. All three factors of irradiation i.e. date, irradiation and temperature affected ascorbic acid loss at the 1% level of significance. The Tubers irradiated on the 50th day after harvest which were physiologically older lost 20.6% ascorbic acid during storage. Minimum loss (15.2%) was observed in the tubers irradiated on the 10th day after harvest. Irradiation levels generally tended to decrease ascorbic acid loss at low dosage levels (50 Gy) at all irradiation dates. The loss increased at higher doses

such as 100 and 150 Gy in tubers from all three irradiation dates. 150 Gy irradiation increased ascorbic acid loss from 10.74% (with 100 Gy) to 25.63%. These results agree with the findings of Joshi et al. (1978) and Wang and Chao (2003). Storage at higher temperature (16°C) generally resulted in greater loss of ascorbic acid (20.34%) as compared to low temperature (8°C) which caused 13.4% loss. But the tubers of the higher temperature storage irradiated earlier after harvest had less loss compared to the non-irradiated tubers which were sprouted.

Irradiation with 150 Gy on the 10th day and 100 Gy dose on the 50th day after harvest on tubers resulted in comparable losses at both 8 and 16°C temperatures (Figures 6). This indicates that higher temperature storage requires higher doses of irradiation for the extension of shelf life of potato tubers as higher irradiation counteracts the effect of higher storage temperature. Storage temperature played an important role in the ascorbic acid loss.

Interaction of irradiation date and temperature significantly ($p < 0.01$) increased the loss of ascorbic acid, where the magnitude of loss was greater in the

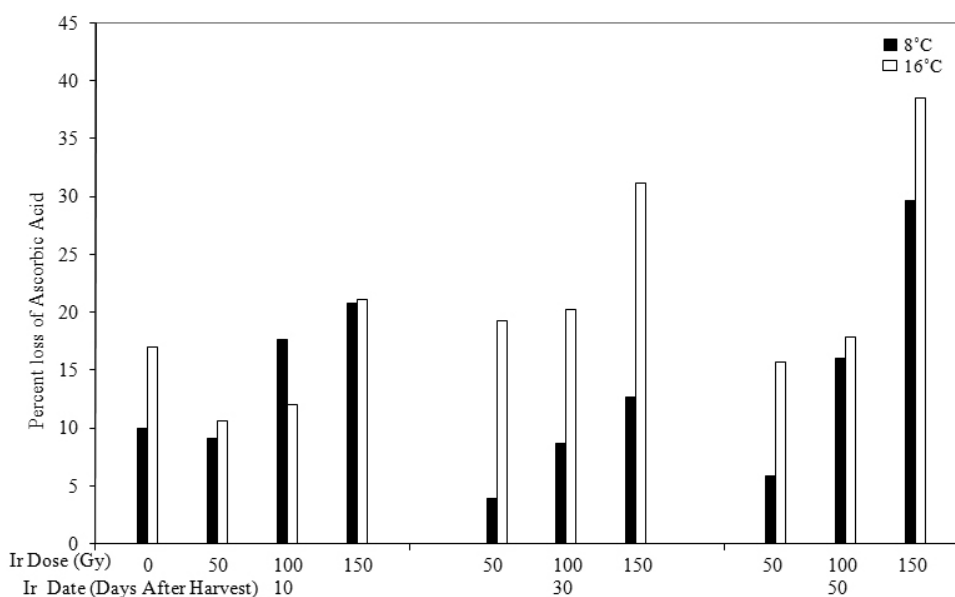


Figure 6. Irradiation effects on percent loss of ascorbic acid of Agria potato tubers irradiated in different dates and stored for five months at 8 and 16°C .



tubers irradiated later after harvest. Interaction of irradiation and temperature also significantly ($p < 0.05$) increased the loss of ascorbic acid. This may be due to increased metabolism of ascorbic acid and biosynthesis of carbohydrates or its oxidation to dehydroascorbic acid (Trautner and Somogyi, 1964). The 150 Gy irradiation treatments caused the greatest loss of ascorbic acid. The tubers irradiated with more delay after harvest were subject to greater loss of ascorbic acid in response to higher doses of irradiation and higher storage temperature. Potato tubers in active metabolic state or not fully dormant seem to be more sensitive to irradiation as indicated by IAEA (1982) that living organisms suffer more irradiation injury.

CONCLUSIONS

Agria potato tubers widely grown in Iran were studied for the application of Gamma irradiation in prolonged storage. Previous findings had already revealed that potato should not be stored below 8°C in order to prevent low-temperature sweetening phenomena and storage at temperature higher than 8°C involves, however, a practical problem for long term storage due to sprouting and loss in firmness and weight. The results of this study indicated significant effects of irradiation dates, irradiation and temperature levels on sprout inhibition, weight loss and specific gravity of tubers. Tubers irradiated immediately after harvest displayed no sprouting when irradiated and stored at 8°C while storage at 16°C caused some sprouting even when irradiated with 100 Gy dose on the 30th and 50th days after harvest. Non-irradiated tubers sprouted extensively and were not suitable for any use. The sprout inhibition effect of irradiation may be the basis for physical and biochemical changes in tubers during storage. Higher storage temperature (16°C) increased the detrimental changes due to temperature. Reduction sugars and sucrose

contents were significantly increased by delay in irradiation and higher irradiation levels. The least sprouting and change in reducing sugars were observed in the tubers irradiated immediately after harvest. Irradiation in general tended to increase the loss of ascorbic acid with dosage increase. This was greater at higher storage temperature and delay in irradiation and therefore, delay in irradiation and storage at high temperature are not recommended. The application of 50-150 Gy of ionizing radiation to potato tubers induced noticeable improvement to maintain firmness, and it was found to be an effective post harvest treatment for sprout suppression during long term storage at elevated temperature (8°C).

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REFERENCES

1. Afshari, H. 2006. Examination of Mechanical Properties and Impact Sensitivity of Potato Varieties and Mathematical Modeling of Tuber Damage Susceptibility. Ph.D. Thesis. Mechanics of Farm Machinery, Faculty of Agriculture, Sciences and Researches Branch, Islamic Azad University. Iran. P. 180.
2. Arvanitoyannis, I. S., Stratakis, A. C. and Tsarouhas, P. 2009. Irradiation Applications in Vegetables and Fruits: A Review. *Crit. Rev. Food Sci. Nutr.* **49(5)**: 427-462.
3. Arvanitoyannis, I. S., Vaitis, O., Mavromatis, A. 2008. Potato: A Comparative Study of the Effect of Cultivars and Cultivation Conditions and Genetic Modification on the Physio-chemical Properties of Potato Tubers in Conjunction with Multivariate Analysis Towards Authenticity. *Crit. Rev. Food Sci. Nutr.* **48(9)**: 799-823.

4. Badshah, N., Iritani, W. M., Rom, C. R. and Patterson, M. E. 1990. Studies on the Sugars Development of Irradiated Potatoes Receiving Different Nitrogen Levels During Growth and Stored at Different Temperatures. *Acta Hort.* (ISHS) **269**: 267-276.
5. Beutler, H. O. and Beinstingl, G. 1980. Determination of L-ascorbic Acid in Food. *German Food-Rundschau* **76**: 68-75.
6. Bidawid, S., Farber, J. M. and Sattar, S. A. 2000. Inactivation of Hepatitis A Virus (HAV) in Fruits and Vegetables by Gamma-Irradiation. *Int. J. Food Microbio.* **57**: 91-97.
7. Brierley, E. R., Bonner, P. L. R. and Cobb, A. H. 1996. Factors Influencing the Free Amino Acid Content of Potato (*Solanum tuberosum* L.) Tubers during Prolonged Storage. *J. Sci. food Agric.* **70**: 515-552.
8. Brynjolfsson, A. 1989. Future Radiation Sources and Identification of Irradiation Foods. *Food Technol.* **43**: 84-89, 97.
9. Burton, W. G., Horne, T. and Powell, D. B. 1959. The Effect of Gamma Irradiation upon the Sugar Content of Potatoes. *Eur. Potato J.* **2**: 105-112.
10. Burton, W. G. and De Jong, W. H. 1959. The Irradiation of Ware Potatoes. *Int. J. Appl. Radiat. Isotop.* **6**: 183-188.
11. Chachin, K. and Iwata, T. 1981. Respiratory Metabolism and Potassium Release of Irradiated Potatoes. In: *Seminar on food Irradiation for Developing Countries in Asia and the Pasific*, in November in Tokyo. Japan. Paper No. IAEA-SR-60/15. P. 131.
12. Farkas, J. 1985. Present status and prospects for the commercialization. IAEA, Vienna, 73.
13. Fiszer, W., Zabielski, J. and Morz, J. 1985. Preservation of Potatoes by Irradiation and Economic Considerations. Lab of Nuclear Methods in Agriculture, University of Agriculture, Poznan, Poland. P. 101-108.
14. Food and Agricultural Organization. 2007. <http://faostat.fao.org/>
15. Frazier, M. J., Kleinkopf, G. E., Brey, R.R. and Olsen, N.L. 2006. Potato Sprout Inhibition and Tuber Quality After Treatment with High-energy Ionizing Radiation. *Am. J. Potato Res.* **83**: 31-39.
16. Freeman, K. L., Franz, P. R. and De Jong, R. W. 1998. Effect of Phosphorus on the Yield, Quality and Petiolar Phosphorus Concentrations of Potatoes (cvv. Russet Burbank and Kennebec) Grown in the Krasnozern and Duplex Soils of Victoria. *Aust. J. Exp Agr.* **38(1)**: 83 - 93
17. Golachowski, A. 1985. Properties of Starch Obtained from Potato Tubers Influenced by Various Temperatures. *Starch-Starke* **37**: 263-266.
18. Gökman, V., Akbudak, B., Serpen, A., Acar, J., Turan, Z. M. and Eris, A. 2006. Effects of Controlled Atmosphere Storage and Low-dose Irradiation on Potato Tuber Components Affecting Acrylamide and Color Formations upon Frying. *Euro. Food Res. Tech.* **244**: 681-687.
19. Hayashi, T. and Kawashima, K. 1982. The Effect of Gamma Irradiation on the Sucrose Content in Sweet Potato Roots and Potato Tubers. *Agr. Biol. Chem.* **46(6)**: 1475-1479.
20. Hayashi, T. and Asoka, S. 1985. Effects of Irradiation on the Carbohydrate Metabolism Responsible for Sucrose Accumulation in Potatoes. *J. Agr. Food Chem.* **33 (1)**: 14-17.
21. Hayashi, T. 1988. Identification of Irradiation of Potatoes by Impedemetric Methods. In: *Health Impact Identification and Dosimetry of Irradiated Foods*. Report of WHO Working Group. Institute for Strahlenhygiene des Bundesgesundheitsamtes, Neuherberg, Germany. p. 432-452.
22. Hughes, R. E., Hurley, R. J. and Jones, P. R. 1971. Vitamin C activity of D-araboascorbic acid. *Nutr. Rep. Int.* **4**: 177-183.
23. IAEA. 1982. Training manual of food on irradiation and techniques. Vienna, **2**: 36-61.
24. Iritani, W. M., Weller, L. and Russel, T. S. 1973. Relative Differences in Sugar Content of Basal and Apical Portions of Russet Burbank Potatoes. *Am. Potato J.* **50**: 24-31.
25. Joshi, M. R., Srirangarajan, A. N. and Thomas, P. 1990. Effects of Gamma Irradiation and Temperature on Sugar and Vitamin C Changes in Five Indian Potato Cultivars during Storage. *Food Chem. J.* **35**: 209-206.
26. Joshi, M. R., Srirangarajan, A. N. and Thomas, P. 1978. Unpublished data. In: "Radiation Preservation of Food of Plant Origin. I. Potatoes and other tuber crops. *Crit. Rev. Food Sci. Nutr.* **19(4)**: 327-374.
27. Kameyama, K. and Ito, H., 2000. Twenty-Six Years of Commercialization on Potato Irradiation at Shihoro, Japan. *Radiat. Phys. Chem.*, **57**: 227-230.



28. Knowles, N. R. 1983. The Physiology of Senescence in Russet Burbank Seed-tubers: a Characterization of Age-reduced Vigor and Tuber Metabolism. Ph.D. Washington State Univ. Pullman, WA.
29. Kovacs, E., Van Buren, J. P., Pitifer, L. A., Hoch, H. C. and Terhune, B. T. 1997. Effect of Irradiation and Storage on Cell Wall Structure of Golden Delicious and Empire Apples. *Acta Aliment.* **26**: 171-190.
30. Kumar, S., Khade, H. D., Dhokane, V. S., Behere, A. G. and Sharma, A. 2007. Irradiation in Combination with Higher Storage Temperature Maintains Chip-Making Quality of Potato. *Food Sci. J.* **72**: 402.
31. Luther, T., Hübner, G., Grahn, C. and Döllstädt, R. 1990. Studies on Potato Irradiation in the G.D.R., *Radiat. Phys. Chem.*, **36**: 657-660.
32. Macqueen, K. F. 1965. Sprout Inhibition of Vegetables Using Gamma Irradiation. In: Radiation Preservation of Foods. Proceeding of an International Conference, in September in Boston, Massachusetts. Published by National Research Council-National Academy of Sciences, Washington D. C. P.127-136.
33. Majd, F. and Ardakani, M. R. 2003. Nuclear Techniques in Agricultural Sciences. Tehran University Press. 330-352
34. Matsuyama, A. and Umeda, K. 1983. Sprout Inhibition in Tubers and Bulbs. In: Preservation of Food by Ionizing Radiation, Vol. III (eds. Josephson, E. S. and Peterson, M. S.). CRC Press, Boca Raton, Florida, P. 159-166.
35. Mehta, A. and Kaul, H. N. 1991. Effect of Sprout Inhibitors on Potato Tubers (*Solanum tuberosum* L.) Stored at Ambient or Reduced Temperatures. *Potato Res.* **34(4)**: 443-450.
36. Nouri, J. and Toofanian, F., 2001. Extension of Storage of Onions and Potatoes by Gamma Irradiation. *Pak. J. Biol. Sci.*, **4(10)**: 1275-1278.
37. Ogava, M and Hayodo, H. 1989. Biochemical Effects of Gamma Radiation on Potato and Sweet Potato Tissues. *Agr. Biol. Chem.* **33**: 1220-1222.
38. Olson, G. 1998. Irradiation of Food. A Scientific Status Summary by the Institute of Food Technologists, Expert Panel of Food Safety and Nutrition. Chicago, **52(1)**:56-62.
39. Prakash, A., Monley, J., Decosta, S., Coporasa, F. and Foley, D. 2002. The Effects of Gamma-irradiation in the Microbiological Physical and Sensory Qualities of Diced Tomatoes. *Radiat. Phys. Chem.* **63**: 387-390.
40. Rastogi, N. K. 2005. Impact of Gamma Irradiation on Some Mass Transfer Driven Operations in Food Processing. *Radiat. Phys. Chem.* **73**: 355-361.
41. Rastogi, N. K., and Raghavarao, K. S. M. S. 2004. Increased Mass Transfer during Osmotic Dehydration of Irradiated Potatoes. *J. Food Sci.* **69**: 259-263.
42. Revathy, B., Usha Devi, A., Nayak, C. A., Kudachikar, V. B., Keshava Prakash, M. N., Prakash, M., Ramana, K. V. R. and Rastogi, N. K. 2006. Effect of Low-dose γ -Irradiation on the Shelf Life and Quality Characteristics of Minimally Processed potato Cubes under Modified Atmosphere Packaging. *Radiat. Phys. Chem.* **76**: 1042-1049.
43. Schwimmer, S., Buss, H. K., Harrington, W. D. and Seston, W. J. 1957. Gamma Irradiation of Potatoes: Effect of Sugar Content, Chip Color, Germination, Greening and Susceptibility to Mold. *Am. Potato J.* **34**: 31-41.
44. Shekhar, V. C., Iritani, W. M. and Arteca, R. 1978. Changes in Ascorbic Acid Content during Growth and Short-term Storage of Potato Tubers (*Solanum tuberosum* L.). *Am. J. Potato Res.* **55**: 663-670.
45. Singh, J. and Kaur, L. 2009. Advances in Potato Chemistry and Technology. Academic press, PP. 348-355
46. Sparks, W. C. and Iritani, W. M. 1964. The Effects of Gamma Rays from Fission Products Wastes on Storage Losses of Russet Burbank Potatoes. Agricultural Experiment Station, Department of Plant Science, College of Agriculture, University of Idaho. *Research Bulletin No* 60: 27.
47. Sweeny, J. P., Hepner, P. A. and Liebeck, S. Y. 1969. Organic Acids, Amino Acids and Ascorbic Acid Content of Potatoes as Affected by Storage Conditions. *Am. Potato J.* **46**: 463-469.
48. Takano, H., Akoki, S., Umeda, K. and Sato, T. 1974. Sprout Inhibition of Potatoes by Ionizing Radiation. Part 4. Effect of Gamma Irradiation on the Cure of Wounded

- Potatoes. *Report, National Food Research Institute* **29**: 48-54.
49. Thomas, P. 1984. Radiation Preservation of Food of Plant Origin. Part I. Potatoes and Other Tubers Crops. *Crit. Rev. Food Sci. Nutr.* **19(4)**: 327-379.
50. Trautner, K. and Somogyi, J. C. 1964. Biosynthesis of Vitamin C in Potato Slices. *Intern Z vitamin Forsch* **34**: 433-435.
51. Umeda, K. H., Takano, H. and Sato, T. 1969. Sprout Inhibition of Potatoes by Ionizing Irradiation. 1. Effect of Delay Between Harvest and Irradiation on Sprouting. *J. Food Sci. Technol.* **16**: 508-515.
52. Ussaf, K. K. and Nair, P. M. 1972. Metabolic Changes Induced by Sprouting Inhibition Dose of Gamma Irradiation in Potatoes. *J. Agr. Food Chem.* **20**: 282-???
53. Wang, J., Chao, Y., 2003. Effect of Gamma Irradiation on Quality of Dried Potato. *Rad. Phys. Chem.*, **66**: 293-297.
54. WHO. 1999. *High dose irradiation in wholesomeness of food irradiated with dose above 10 KGy*. WHO Technical Report Series 890. World Health Organization. Geneva. P. 9-37.
55. Wierbicki, E. 1986. Ionizing Energy in Food Processing and Pest Control: I. Wholesomeness of Food Treated with Ionizing Energy. Council for Agricultural Science and Technology (CAST), Ames, Iowa. Repot No 109. P.50.
56. Wilkinson, V. M. and Gould, G. W. 1996. *Food irradiation. A Reference Guide*; Read Educational and Professional Publishing Ltd, Oxford. p. 177
57. Yamaguchi, M. G., Perdue, J. and Macgillivray, J. 1960. Nutrient Composition of White Rose Potatoes during Growth and Storage. *Am. Potato J.* **37**: 73-76.

عدم جوانه زنی و کیفیت غده های سیب زمینی بعد از تیمار شدن با پرتو گاما در زمان های مختلف بعد از برداشت

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چکیده

انبارداری سیب زمینی دارای اهمیت زیادی می باشد زیرا سیب زمینی تازه برداشت شده فقط برای چند ماه در سال در دسترس است. بنابراین راهکارهای مختلفی از جمله پرتوتابی گاما جهت کنترل جوانه زنی و افزایش انبارمانی قابل ارائه می باشد. در این مطالعه ممانعت از جوانه زنی و کیفیت غده های سیب زمینی بعد از تیمار شدن با پرتو گاما در زمان های مختلف بعد از برداشت (۳۰، ۱۰ و ۵۰ روز بعد از برداشت) در طول انبارداری در دماهای ۱۰ و ۱۶ درجه سلسیوس با استفاده از غده های رقم آگریا صورت گرفت. غده ها با دوزهای ۵۰، ۱۰۰ و ۱۵۰ گری از پرتو گاما پرتوتابی شدند. این مطالعه با یک آزمایش فاکتوریل بر مبنای طرح اسپیلیت پلات با سه تکرار انجام گردید. حداقل میزان جوانه زنی (۰/۰۱ ± ۴/۸۳) در غده هایی که زودتر پرتوتابی شده بودند (۱۰ روز بعد از برداشت) مشاهده شد. این مطالعه نشان داد که پرتوتابی زودتر و سطوح پرتوتابی به طور معنی دار باعث کاهش جوانه زنی، درصد وزن تلف شده و وزن مخصوص غده ها می شوند. میزان تلفات اسید اسکوربیک و مقدار قندهای احیا و



ناحیا به طور معنی دار با تاخیر در پرتوتابی افزایش و میزان قندها و سطح اسید اسکوربیک در اثر پرتوتابی کاهش یافت و افت مربوط به سفتی بافت بعد از ۵ ماه انبارداری در غده های پرتوتابی نشده صورت گرفت. دمای بالاتر انبار (16°C) باعث تلفات بیشتری (۲۰/۳۴٪) در میزان اسید اسکوربیک گردید و غده های انبار شده در در دمای ۱۶ درجه سلسیوس تغییرات متابولیکی بیشتری داشتند که در جوانه زنی و افت وزنی و میزان اسید اسکوربیک و قندها نمایان گردید. پرتوتابی با دوز ۵۰ گری که ۱۰ روز بعد از برداشت صورت گرفت باعث ممانعت کامل از جوانه زنی غده هایی شد که در دمای ۱۰ درجه سلسیوس نگهداری شدند و دوز ۱۵۰ گری با وجودی که از جوانه زنی در دمای ۱۶ درجه سلسیوس جلوگیری نمود بیشترین تلفات اسید اسکوربیک را به همراه داشت. غده های پرتوتابی شده با تأخیر بیشتر تلفات اسید اسکوربیک بیشتری در مقابل دوزهای بالاتر پرتوتابی و دمای بالاتر داشتند در نتیجه جهت کاهش تغییرات نامطلوب در غده های سیب زمینی آگریا، تاخیر در پرتوتابی و انبارداری با دمای بالا پیشنهاد نمی شود.