KOREAN J. FOOD SCI. TECHNOL.
Vol. 16, *No.* 4 (1984)

Effect of Gamma Irradiation on the Physiological Characteristics of Garlic Bulbs During Storage

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감마선조사가 저장중 마늘의 생리적 특성에 미치는 영향

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Abstract

This study was intended to investigate the physiological effect of gamma irradiation at 50, 100 and 500 Gy on the garlic bulbs stored at low temperature of 3±1°C and a relative humidity of 70-80%, and room temperature of 12±5°C and a relative humidity of 75-85%, respectively for 10 months. Irradiation treatment stimulated temporary the respiration of garlic, which was greatly affected by storage conditions later. Sprouting of garlic was effectively inhibited in the all irradiated and low temperature groups until 10 months of storage, while the nonirradiated and 50 Gy groups were partially rooted around the 4th month after storage under both conditions. Weight loss and spoilage were shown to be little affected by irradiation until the nonirradiated garlic sprouted, and at the latter stage of storage period, the optimum dose of irradiation showed a significant effect on the reduction of weight loss and spoilage in stored garlic. It was also found that irradiation for sprout inhibition did not influence the firmness of garlic cloves.

Introduction

In order to meet the increasing need for food throughout the world, many approaches have been utilized, and recently the reduction of food loss during storage is being recognized as one of the important factors in food supply.

The fact that ionizing radiation has a characteristic effect on living things has been known since Roentgen (1895) and Becquerel (1896) discovered the exsistence of X-rays and radioactivity, respectively. In connection with food irradiation, Schwartz[1] attempted the first real application of X-rays to kill *Trichinella spiralis* in meat. The process of food irradiation involves exposing the food to ionizing radiation so that a prescribed quantity of radiation is absorbed. Radiation sources used for food irradiation are gamma-rays from the nuclides Co-60 or Cs-137, electron beams and X-rays generated from machine sources operated at or below an energy level of 10 MeV, respectively.

It has been well illustrated that the applications of radiation doses are classified depending upon desirable objectives, and also that the inhibition of sprouting can be possible with relative low doses of below 150 Gy (1 Gy = 100 rad = 1 *J/kg*).[2,3]

Regarding the wholesomeness of irradiated foods, the Joint FAO/IAEA/WHO Expert Committee, in 1980, concluded that the irradiation of any food commodity up to an overall average dose of 10 kGy presents no toxicological, nutritional and microbial problems,[3,4] and more recently, the US FDA permitted the use of irradiation at doses not to exceed 1 kGy for inhibiting the growth and maturation of fresh fruits and vegetables, and insect disinfestation of food, and also at doses not exceeding 30 kGy for microbial sterilization of spices.[5] Accordingly, as of April 1984, twenty eight countries have approved collectively about forty-five irradiated food items for human consumption on either an unconditional or a restricted basis.[6]

Garlic has been inevitably used as a raw vegetable and condiment in our dietary life from the ancient times. It has been said that 1,300 years ago, our ancestors hung garlic bulbs in airy shade after harvest and then made a heap with chaffs for winter preservation. Since then, this traditional method has been mostly used by farmers, but after the dormant period of 2 to 3 months after harvest, almost all of the stored garlics sprout and the additional loss due to spoilage and weight loss is serious.[7,8]

Therefore, to reduce the storage loss of garlic, maleic hydrazide (MH) treatment[9,10] and mechanical cold temperature storage methods[11,12] have been studied and are being partially utilized in commercial operations in Korea. However, many problems remain to be investigated with respect to the satisfactory inhibition of sprouting, chemical residues, and storage cost and capacity.

Since Sparrow and Christensen[13] first reported that Co-60 gamma radiation had an effect on sprout inhibition in potato tubers, many investigators have confirmed its effectiveness for other bulb and tuber crops, and additionally the irradiated foods have been numberously investigated concerning biochemical and physiological aspects.

As to irradiated garlic, however, some physicochemical changes were only partly studied during storage by several researchers,[8,14,15] and that in relation to the maintaining the quality of garlic bulbs; the physiological effects of ionizing radiation has been hardly investigated, especially in Korea.

This research deals with the effects of gamma irradiation on the physiological properties of garlic bulbs associated with quality changes during storage.

Materials and Methods

Materials

The garlic (*Allium sativum* L.) used was a Korean local late variety consisting of 6 to 8 cloves and obtained from Changnyung in June, 1982.

The garlic bulbs were cured in circulating air of 22-25 °C and a relative humidity (RH) of 60-65% for 4 weeks after harvest.

Irradiation and Storage

The stems of the cured garlics were cut off at 2 to 3cm from the bulbs, and the bulbs were divided into four groups and irradiated by a 10 kilo curie Co-60 gamma irradiator (dose rate: 25 Gy/hr) with doses of 0, 50, 100 and 500 Gy, respectively.

The irradiated garlic bulbs were packaged individually in perforated plastic boxes (60 × 45 × 45cm) and stored at low (3±1 °C, R.H. 70-85%) and room (12±5 °C, R.H. 75-85%) conditions, respectively for 10 months.

Measurement of Respiratory Rate

The respiratory rate of the garlic bulbs was determined by placing the sample in a desiccator, and then the evolved CO_2 was absorbed in KOH prepared at a bottom. The remaining KOH was titrated with HC1.

Measurement of Sprouting and Rooting

Garlic cloves were dissected with the thin blade and the length of internal sprouts was measured bimonthly. The sprouting rate was expressed as the percentage of sprout length per total clove length.

In addition, to observe the morphorogical changes of inner buds, bud tips dissected from the cloves and cross sections were observed using a microscope (Olympus EHCRTR-3 trinocular) at the 15th day after irradiation. Rooting was measured at regular intervals and expressed as the length (*mm*) of root growth. 100 individual cloves were used for sprouting and rooting tests.

Measurement of Weight Change and Spoilage

Two kilograms of garlic bulbs from each group were weighed at bimonthly intervals, and the cumultative percentage of weight loss was calculated. The spoilage rate was expressed as the number of spoiled cloves per 100 cloves. Evaluation criteria of spoilage were based on the observation of any spmptom among the rot attack, shrinkage and discoloration.

Measurement of Firmness

The garlic cloves were peeled off and their firmness was measured using an Instron (Model 1140) with the following conditions: plunger ϕ, 1.2*mm*; clearance, 2.6*mm*; cross head speed, 100*mm*/min; chart speed, 200*mm*/min; sample height, 13*mm*.

Statistical Analysis

The significance of each factor in observed results was determined according to the analysis of variance and the t-test.

All figures reported here represent the average of triplicate experiments.

Results and Discussion

Respiration of Irradiated Garlic Bulbs

The respiratory rate was measured to evaluate the metabolic response induced by irradiation. As shown in Fig. 1 immediately after irradiation the respiratory rate of 100 and 500 Gy irradiated groups rose more than two times that of the nonirradiated ones, and then it normalized with the lapse of storage time. As a possible explanation for the this effect, it seems that the resultant stress of irradiation elicits an elevated or continued respiration commensurate with repair reactions.

The respiratory rate of the low temperature group was relatively low and constant regardless of irradiation doses during the whole storage period, while that of bulbs in room temperature storage was markedly increased around the 3rd month after storage and after 8 months of storage, especially in the nonirradiated group. Accordingly, it was found that the respiration of garlic bulbs during storage was highly influenced by the irradiation treatment and storage conditions as well.

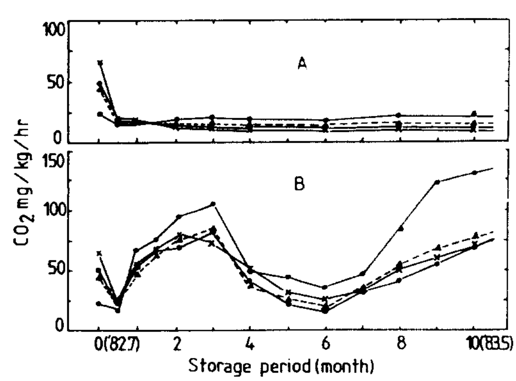

Fig. 1. Changes in respiratory rate of irradiated garlic bulbs during storage at 3±1℃ (A) and 12±5℃ (B)
○—○, 0 Gy; △···△, 50 Gy; ●—●, 100 Gy; ×—×, 500 Gy

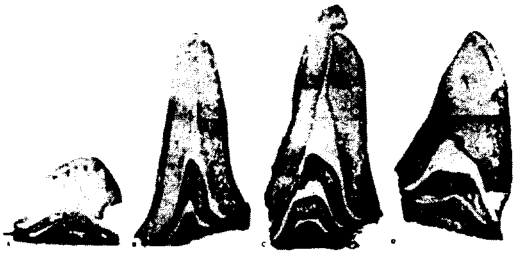

Fig. 2. Morphorogical changes in the inner sprouts of irradiated grrlic bulbs stored at 3±1℃ before dormant break(x 28)
A, 0 Gy; B, 50 Gy; C, 100 Gy; D, 500 Gy

These observed results were consistent with the respiratory patterns of other irradiated vegetables and fruits.[16, 17]

Sprout and Root Inhibition

The effects of gamma irradiation on the sprout inhibition of garlic bulbs are shown in Fig. 2 and 3. The development of inner buds during the dormant period was considerably accelerated by irradiation, but temporary accelerated sprouts did not continue to grow after dormant breaking.

The external sprouting of garlic bulbe was completely inhibited in all irradiated and low temperature groups until 10 months of storage, whereas the nonirradiated bulbs stored at room temperature all sprouted within 8 months of storage.

On the other hand, garlic bulbs of the nonirradiated and 50 Gy groups partially rooted around the 4th month after storage in both storage conditions as shown in Table 1

Recently, the storage of garlic bulbs using gamma irradiation has been investigated by numerous resear-

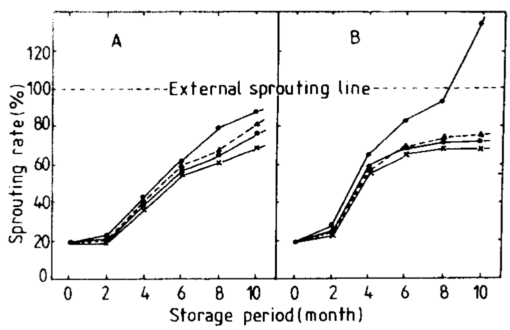

Fig. 3. Effect of gamma irradiation on the sprout inhibition of garlic bulbs during storage at 3±1℃ (A) and 12±5℃ (B)
○—○, 0 Gy; △···△, 50 Gy; ●—●, 100 Gy; ×—×, 500 Gy

Table 1. Root growth of irradiated garlic bulbs during storage[a]

Condition / Period (month) \ Does (Gy)	Low temp. (3 ± 1 ℃) 0	50	100	500	Room temp. (12 ± 5 ℃) 0	50	100	500
4	0.5	0.2	0	0	0.3	0	0	0
6	1.5	0.2	0	0	2.0	0.2	0	0
8	2.2	0.3	0	0	3.3	0.2	0	0
10	3.4	0.3	0	0	4.0	0.3	0	0

[a] Root growth is expressed as the length (*mm*) and each value is the mean for 100 numbers of cloves.

chers, and it has been proposed that irradiation doses of 50 to 150 Gy satisfactory inhibit sprouting and also reduce additional losses during storage.(8, 10, 14, 15) Although it is generally agreed that sprout inhibition is influenced by the physiological state of the sample at the time of irradiation, radiation dose and storage conditions, a dose of 100 Gy which seemed to be the optimum for sprout and root inhibition in this experiment was well in accord with the results of the above investigators.

Reduction of Weight Loss

There are many reports on the effectiveness of gamma irradiation for the reduction of storage loss in addition to sprout inhibition in some vegetables. The weight change of all stored samples showed a decreasing tendency with the lapse of storage period, and at the latter stage of storage the cumultative percentage of weight loss was significantly lower in the irradiated bulbs than in the nonirradiated ones under both conditions ($P<0.05$), as illustrated in Fig. 4 However, there was no significant difference between low and room

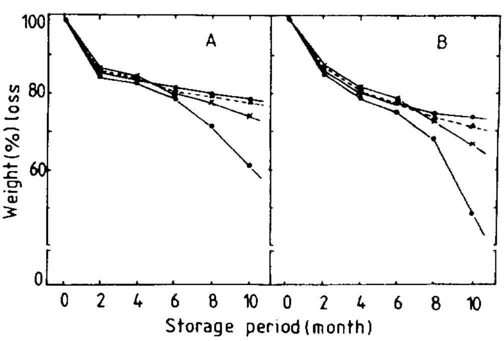

Fig. 4. **Effect of gamma irradiation on the weight loss of garlic bulbs during storage at 3± 1℃ (A) and 12± 5℃ (B)**
○—○, 0 Gy; △···△, 50 Gy; ●—●, 100 Gy; ×—×, 500 Gy

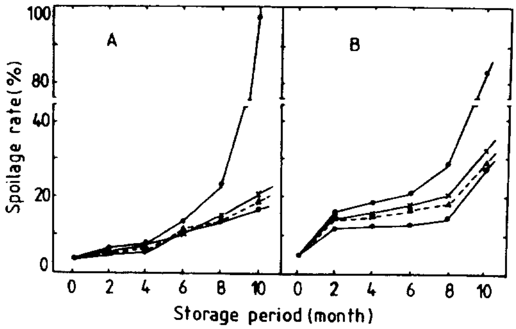

Fig. 5. **Effect of gamma irradiation on the spoilage of garlic bulbs during storage at 3± 1℃ (A) and 12± 5℃ (B)**
○—○, 0 Gy; △···△, 50 Gy; ●—●, 100 Gy; ×—×, 500 Gy

temperature groups, and the weight loss was shown to be little affected by irradiation until the nonirradiated garlics sprouted.

As already indicated by Mathur(15) and Hendel and Burr,(18) the physiological loss in weight is chiefly due to the transpiration and respiration of the stored foods, and so it is suggested that the optimum irradiation dose for sprout inhibition and well controlled environmental conditions can minimize the weight change of garlic bulbs during storage.

Reduction of Spoilage

Fig. 5 shows the effects of gamma irradiation on spoilage of stored garlics. The initial spoilage rate of garlic bulbs was about 3%, and it increased during storage in all groups. In general, no statistical difference was shown among the treated groups at the earlier period of storage. However as the storage time increased, the percentage of spoiled cloves was significantly higher in the nonirradiated group than in the irradiated ones, expecially at low temperature.

It has been known that most of the rotten cloves of garlic bulbs resulted from fungi infection,(9, 14) and in order to reduce the loss due to rot attack, stored samples should be selected for ripeness and soundness before irradiation.

Considering the whole storage period, there was a highly significant difference between both storage conditions ($P<0.01$); and the samples stored at room temperature showed a considerable change in spoilage rate depending upon irradiation doses.

Firmness

The most noticeable factor next to sprouting in the

Table 2. Changes in firmness or irradiated garlic bulbs during storage[a]

Condition / Dose (Gy) / Period (moth)	Low temp. (3 ± 1 ℃)			Room temp. (12 ± 5 ℃)		
	0	100	500	0	100	500
0	0.43±0.01[b]	0.42±0.02	0.43±0.02	0.43±0.01	0.42±0.02	0.43±0.02
5	0.34±0.03	0.37±0.02	0.39±0.01	0.36±0.04	0.39±0.02	0.40±0.02
10	0.29±0.03	0.34±0.02	0.32±0.01	0.30±0.02	0.33±0.01	0.31±0.02

[a]Firmness is expressed as the unit of kg/cm^2 and each value is the mean of 10cloves.
[b]mean± standard deviation

quality loss of garlic may be the firmness of the bulbs. Therefore, it is important to observe whether or not irradiation treatment for sprout inhibition causes a change in the firmness of garlic bulbs, although it has been reported that the high dose irradiation has an effect on the softening of fruit and vegetable tissues.

Changes in the firmness of irradiated garlic bulbs during storage are summarized in Table 2. Irradiation treatment did not influence the firmness of garlic cloves immediately after irradiation, but the firmness of stored garlic decreased with the lapse of storage time, showing a slight difference among each group. After 10 months of storage, the firmness of irradiated cloves was superior to that of nonirradiated ones regardless of storage temperatures.

요 약

감마선 조사(50, 100 및 500 Gy)가 수확후 마늘의 생리적 특성에 미치는 영향을 검토하기 위하여 저온(3±1℃, R. H. 70-80%)과 실온(12±5℃, R. H. 75-85%)에 10개월간 저장하면서 실험을 수행하였다. 마늘의 호흡량은 감마선 조사에 의해 일시적으로 자극되었으며, 기간의 경과에 따라 호흡량은 저장조건에 상당한 영향을 받았다. 모든 조사(照射)구와 저온 저장구는 저장 10개월까지 발아가 완전히 억제되었으나, 비조사구와 50Gy 조사구에서는 저장후 4개월경부터 발근 현상을 보였다. 적정 선량의 감마선 조사는 저장중 마늘의 중량변화 및 변폐율의 감소효과를 나타내었으며, 이와 같은 현상은 비조사구 마늘이 발아되면서부터 유의적인 차이를 보였다. 또한 발아억제를 위한 감마선 조사는 마늘의 견고도에 영향을 미치지 않았다.

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(Received August, 11, 1984)