J. Korean Agric. Chem. Soc.
한국농화학회지 31(2), 147—153(1988)

Chemical Changes in Garlic Bulbs Resulting from Ionizing Energy Treatment at Sprout-Inhibition Dose

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발아억제 선량의 전리에너지가 마늘의 성분변화에 미치는 영향

권중호 · 윤형식* · 변명우 · 조한옥
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초 록

마늘의 품질보존을 위한 수단으로서 전리에너지인 감마선의 이용이 가능해짐에 따라, 발아억제 선량인 0.1kGy 처리와 저장조건(3±1°C, 75~85% R.H.; 12±5°C, 75~85% R.H.)이 마늘의 몇가지 성분변화에 미치는 영향을 조사하였다. 0.1kGy의 감마선 조사는 시료의 수분함량에 거의 영향을 미치지 않았으나 실온저장 10개월 후의 대조시료는 조사시료에 비해 수분함량이 유의적으로 감소되었다($p<0.05$). 발아억제 처리는 저장중 시료의 총당 함량의 변화를 완만하게 하였으며, 저온저장 8개월 후 대조시료의 유리당 함량은 조사시료에 비해 유의적으로 증가되었다. 발아억제 선량의 감마선 처리는 시료의 아스코르브산과 지방산 함량에 거의 영향을 주지 않았으나 아미노산 조성중 글루탐산과 아스파르트산 함량에는 영향을 미치는 것으로 나타났다.

Introduction

Food irradiation is a physical treatment comparable to the heating or freezing of food for preservation. Gamma-ray, one of ionizing energy and most widely used in food and industrial radio-processing, is an electromagnetic radiation of very short wavelength and belongs to the same family as ultraviolet, visible and infrared lights, microwaves and radio waves used for communication.[1]

We have learned to accept the use of other radiations for a wide field of different purposes, including the use of microwaves to cook food. It is therefore reasonable to expect the use of radiation to preserve food will also be accepted.

Food processing by ionizing energy is not a miracle technique capable of solving all problems. However, it can solve specific problems of food loss and complement other established methods, such as refrigeration, chemical preservatives and fumigants, in improving the quality and hygienic state of food.[2]

The biological effects of ionizing radiation on a living organism are associated not only with the impairment of a sensitive site(DNA) controlling the cellular reproduction and synthesis of cell component, but with metabolic changes influencing the chemical composition of it[3]. Many researchers have indicated some of these changes observed in the main constituents, e.g. increased conversion of starch to glucose, and recently various results have been reported

Received January 19, 1988
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concerning the effect of irradiation on the composition of food, such as sugars,[4,5] amino acids,[6,7] fatty acids,[8] and vitamins.[9]

Since one of the outstanding features of food irradiation is the ability to prevent sprouting of root and bulb crops, we have attempted this kind of investigation to reduce the postharvest loss due to sprouting of garlic bulbs. As a result, when the garlic bulbs were irradiated within 45 days after harvest, an irradiation at about 0.1 kGy was shown to be more effective for the inhibition of sprouting as well as the reduction of quality deterioration during storage, compared with conventional storage methods which are being used commercially in Korea but having many problems in points of unsatisfactory inhibition of sprouting, chemical residues, and storage cost and capacity[10~12]

To provide data for the assessment of the nutritional wholesomeness of irradiated garlic bulbs, it might be necessary to carry out informative studies to follow up the changes that take place in some chemical components of garlic bulbs under the influence of ionizing energy treatment and storage. This study, therefore, was to investigate the effects of gamma irradiation at sprout-inhibition dose on the chemical components of garlic bulbs and the changes in the amount of these components during storage.

Materials and Methods

Garlic

The garlic(*Allium sativum* L.) grown in Changnyung was procured from a local market and cured in circulating air at 22~25°C and 60~65% R.H. for 4 weeks after harvest.

Irradiation and Storage

The stems of the cured garlic were cut off at 2~3cm from the bulbs, and the bulbs were irradiated at 0 and 0.1kGy, respectively, using a 10 kilo curie Co-60 gamma irradiator(dose rate: 20Gy/hr). The irradiated garlic bulbs were packaged in perforated plastic boxes(60×45×45cm) and stored for 10 months at low(3±1°C, 75~85% R.H.) and room(12±5°C, 75~85% R.H.) temperatures, respectively.

Determination of Moisture Content

Moisture content of the cloves was determined bimonthly according to the air oven method[13]

Determination of Sugars

The content of total available carbohydrate was determined periodically by the modified-Somogyi method[14] after hydrolysis with 25%-HCl, and also reducing sugar content was calculated in terms of glucose content according to the same method without hydrolysis. The free sugar composition of the garlic was analyzed after 8 months of storage by HPLC(Beckman model 334) packed with Lichrosorb NH_2 10μm. The operating conditions were: flow rate, 2.2 ml/min; mobile phase, acetonitrile; water(80 : 20, V/V); detector, RI; attenuation, 8X.

Determination of Ascorbic Acid

The ascorbic acid content of the garlic was determined by the 2,4-dinitrophenylhydrazine colorimetry[15] at bimonthly intervals during storage.

Determination of Fatty Acids

The lipids of garlic were extracted and purified by the method of Folch et al.[16] immediately after irradiation, and total lipids were subjected to esterification under the method of Metcalfe et al.[17] The fatty acids were fractionated with GLC(Varian aerograph model 3700) on a 2m×2mm i.d. stainless steel column packed with 10% DEGS on Chromosorb W. The operating conditions were: column temperature, 190°C; H_2 flow rate, 30ml/min; injection temperature, 240°C; detector, FID; detector temperature, 250°C. The peak areas of each fatty acid were calculated with the Varian CDS-III data system.

Determination of Amino Acids

Amino acid contents of the garlic were determined immediately after irradiation using amino acid auto-analyzer(Beckman model 116) following acid hydrolysis (6NHCl) for 22 hrs at 110°C. Sulfur-containing amino acids, such as cysteine, cystine and methionine, were measured according to the method of Berner Jr,[18] and the tryptophan content was determined by basic hydrolysis procedures.[19]

Statistical Analysis

The significance of each factor in various observations on the stored garlic was determined according to the t-test. All figures reported here represent the average of triplicate experiments.

Results and Discussion

Moisture Content

The effect of gamma irradiation on the moisture content of garlic bulbs stored at low and room temperatures is given in Table 1. Immediately after irradiation, moisture content of both groups was almost same and during storage, no significant changes in moisture content were

Table 1. Effect of gamma irradiation on the moisture content of garlic during storage[a]

Months in storage	Low temp. (3±1°C)		Room temp. (12±5°C)	
	Irradiation dose(kGy)			
	0	0.1	0	0.1
0	66.6	67.4	66.6	67.4
2	67.1	67.2	67.8	67.6
4	68.3	67.4	67.9	67.2
6	68.6	68.0	68.6	68.8
8	68.1	68.4	66.8	67.1
10	68.0	68.8	64.0[b]	67.8

a : Each value is the mean of triplicate experiments and expressed as percentage(%).
b : Significantly different($P<0.05$) from irradiated group.

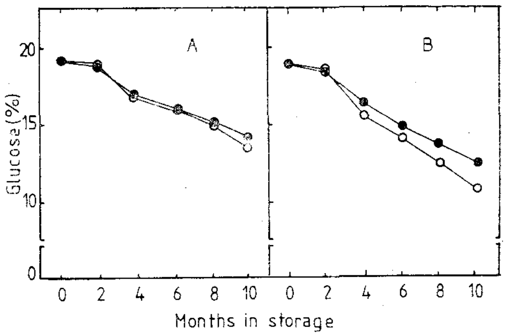

Fig. 1. Effect of gamma irradiation on the total available carbohydrate content of garlic stored at 3±1°C(A) and 12±5°C(B). Each value is the mean of triplicate experiments and expressed as the basis of dry weight.

shown between each group, except for an apparent reduction in the nonirradiated garlic stored at room temperature for 10 months. The reduced content of moisture in nonirradiated garlic at the final stage of storage might be attributed to high rates of transpiration of growing sprouts at room temperature and physical deterioration of the stored bulbs.[11]

Sugar Content

It is well known that the change of storage reserves is largely dependent not only upon the conditions of storage, but also upon the physiological state of the food, such as sprouting, and that amylase activity increases markedly upon sprouting, when it becomes necessary to mobilize carbohydrate for transport to the developing shoot.

The total available carbohydrate content of the garlic is shown in Fig. 1 as a function of irradiation treatment and storage condition. All stored garlic contained a relatively constant amount of total available carbohydrate until 2 months after storage, and thereafter the content gradually decreased in both storage conditions, showing a significant difference between nonirradiated and irradiated samples stored at room temperature($P<0.05$). At the end of the storage period, total available carbohydrate content of irradiated garlic was higher than that of nonirradiated garlic, and so it can be stated from this result that sprout inhibition by irradiation results in the reduction of the changes in total carbohydrate content of stored garlic.

The reducing sugar content of irradiated garlic tended to somewhat increase during the whole storage period, showing some fluctuation, while that of nonirradiated garlic significantly rose at the latter stage of storage in both conditions($P<0.01$) (Fig. 2). Also, after 8 months of storage, the content of free sugars which consisted of sucrose, fructose, and glucose was considerably higher in nonirradiated garlic than in irradiated garlic, especially in low temperature storage (Table 2).

Many investigators have reported that the reducing sugar content of fresh vegetables increased during storage, particularly if stored in cold storage.[6,20] The results of this study are in accordance with the previous findings on some irradiated foods[21,22] and lead to the possibility that gamma irradiation may cause the compositional changes in stored root and bulb vegetables to be inhibited in sprouting.

Ascorbic Acid Content

The ascorbic acid content of stored garlic, as shown in Table 3, tended to gradually decrease

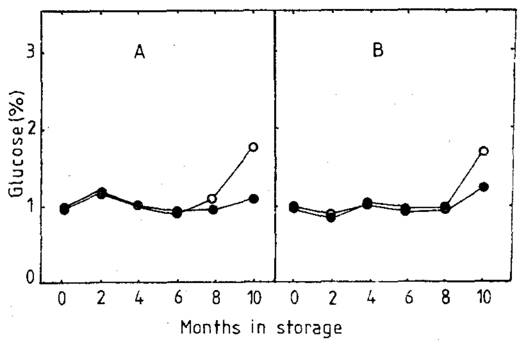

Fig. 2. Effect of gamma irradiation on the reducing sugar content of garic stored at 3±1°C (A) and 12±5°C(B). Each value is the mean of triplicate experiments and expressed as the basis of dry weight.

Table 2. Effect of gamma irradiation on the free sugar content of garlic[a]

sugars	Low temp. (3±1°C)		Room temp. (12±5°C)	
	Irradiation dose(kGy)			
	0	0.1	0	0.1
Fructose	0.96	1.02[b]	0.92	1.04
Glucose	0.78	0.80	1.09	0.81
Sucrose	15.78	11.05[c]	12.25	9.42
Total	17.52	12.87	14.26	11.27

a : Each value is the mean of triplicate experiments. Free sugars were analyzed after 8 months of storage and expressed mg per g on the basis of dry weight.
b : Significantly different ($P<0.05$) from nonirradiated group.
c : Significantly different ($P<0.01$) from nonirradiated group.

Table 3. Effect of gamma irradiation on the ascorbic acid content of garlic during storage[a]

Months in storage	Low temp. (3±1°C)		Room temp. (12±5°C)	
	Irradiation dose (kGy)			
	0	0.1	0	0.1
0	10.8	10.7	10.8	10.7
2	10.8	10.5	10.0	9.3
4	10.0	9.8	9.4	9.3
6	10.2	11.0	8.6	9.2
8	9.6	11.4	9.4	9.0
10	10.8	10.0	10.6	10.4

a : Each value is the mean of triplicate experiments and expressed as mg per 100g on the basis of dry weight.

with the time of storage in both conditions, although intensive metabolism of nonirradiated garlic was partially manifested by changes in the content at the termination of storage. Gamma irradiation at sprout-inhibition dose, however, showed no apparent effect on the content of ascorbic acid. Park *et al.*[23] reported ascorbic acid content of garlic largely decreased by irradiation treatment at 0.3 to 3.0kGy, while Bandyopadhyay *et al.*[24] found no significant change in the ascorbic acid content of irradiated onions up to a dose of 0.5kGy over 3 months of storage as compared with nonirradiated onions. Considering the previous reports and our results, it seemed that the change in ascorbic acid content of sprouting food might not be based on direct chemical reactions induced by irradiation, but be based on the influence of irradiation and storage conditions on the metabolism of it.[25]

Fatty Acid Composition

The main effects of radiation on fats are the formation of peroxide[26] and volatile carbonyl compounds,[27] which are chiefly responsible for imparting rancidity and off-flavors to irradiated foods.

The present work relates to the effect of gamma irradiation at sprout-inhibition dose, 0.1 kGy, on fatty acids of the garlic. The predominant fatty acids of garlic lipids were shown to be linoleic acid, palmitic acid, oleic acid, and linolenic acid, and no important difference of fatty acid contents could be detected between nonirradiated and irradiated samples(Table 4). Tipples and Norris[28] reported that gamma irradiation levels of 100kGy lowered levels of unsaturated fatty acids in food, while it has been observed that irradiation treatment of 60kGy did not significantly alter the fatty acid composition of some vegetable oils.[8] Form these obtained results, it can be proposed that the irradiation dose applied in this study seems to be insufficient to change the fatty acid composition of garlic.

Table 4. Effect of gamma irradiation on the fatty acid composition of garlic[a]

Fatty acids	Irradiation dose(kGy)	
	0	0.1
12 : 0	0.88	0.85
14 : 0	4.84	4.98
16 : 0	22.69	22.72
18 : 0	0.85	0.81
18 : 1	12.31	12.42
18 : 2	51.27	51.47
18 : 3	7.16	6.75

a : Fatty acids were analyzed immediately after irradiation and expressed as percentage(%) of individual fatty acid per total fatty acid fractionated. Each value is the mean of triplicate experiment.

Amino Acid Composition

The main objective of this assessment was to determine whether irradiation treatment for sprout inhibition affected the content of amino acids in garlic, especially that of sulfur-containing amino acids. The results on amino acids of irradiated garlic are shown in Table 5. The

Table 5. Effect of gamma irradiation on the amino acid content of garlic[a]

Amino acids	Irradiation dose(kGy)	
	0	0.1
Lysine	8.67	8.94
Histidine	2.85	2.91
Arginine	40.99	41.67
Aspartic acid	14.57	12.75[b]
Threonine	3.55	4.33
Serine	5.18	6.03
Glutamic acid	40.57	35.21[b]
Proline	4.67	4.73
Glycine	5.42	5.97
Alanine	4.82	5.24
Valine	6.54	7.00
Methionine	1.67	1.67
Isoleucine	3.30	3.79
Leucine	6.70	7.48
Tyrosine	2.97	3.61
Phenylalanine	4.85	5.42
Tryptophan	1.48	1.54
Half-Cystine	3.67	3.33
Total	162.47	161.62

a : Amino acids were analyzed immediately after irradiation and expressed as mg per g on the basis of dry weight. Each value is the mean of triplicate experiments.

b : Significantly different ($P<0.05$) from nonirradiated group.

most sensitive amino acid appeared to be the glutamic acid and aspartic acid, showing a significant reduction in their amounts, while lysine, valine, leucine, etc. showed a slight increase upon irradiation. The data also indicate that an irradiation dose at 0.1kGy shows no significant effect on the content of sulfur-containing amino acids such as methionine, cysteine and cystine. This result is in partial agreement with the findings on the irradiated onions[6] and dates,[7] and the compositional difference of amino acids between nonirradiated and irradiated groups seems not to change the nutritional or organoleptic properties of garlic.

Abstract

An assessment of the nutritional aspects on irradiated garlic bulbs, stored for 10 months at low(3±1°C, 75~85% R.H.) and room(12±5°C, 75~85% R.H.), was performed by means of investigations on the changes in some chemical composition. Ionizing energy treatment at 0.1 kGy gamma-ray brought about no significant changes in the moisture content of stored garlic, but it contributed to the reduction of the changes in total available carbohydrate content of stored garlic. After 8 months of storage, the content of free sugars was significantly higher in nonirradiated garlic than in irradiated garlic, especially in low temperature storage. The 0.1kGy irradiation at the sprout-inhibition dose had no apparent effect on the content of ascorbic acid in stored garlic, and sulfurcontaining amino acids appeared to be little affected by the irradiation at 0.1kGy, even though there were some sensitive amino acids like glutamic and aspartic acids.

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