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The Effects of Radiation and Extended Storage on the Chemical Quality of Garlic Bulbs

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ABSTRACT

Several chemical parameters were investigated in 'red' variety garlic, irradiated to inhibit sprouting, with doses of 30 Gy and kept under warehouse conditions. The studies were conducted between 210 and 270 days post harvest (critical marketing periods) when this variety was not normally available for raw consumption.

It was found that, during storage, the irradiated garlic showed a significant increase in ascorbic acid content but no change in dry matter content compared with non-irradiated garlic. Compared with non-irradiated garlic, at 270 days' storage, the irradiated garlic had a higher index of flavour, measured as enzymatic pyruvate, a higher acidity and a lower content of water-soluble carbohydrates.

From these observations, the irradiated garlic should be suitable for prolonged storage with the object of marketing it during critical periods.

INTRODUCTION

Several researchers have proved the efficacy of the radioinhibition process in some varieties of garlic bulbs under different storage conditions and different conditions of irradiation (Mathur, 1963; Kahan & Padova, 1966; El-Oksh *et al.*, 1971; Fernández & Arranz, 1979). Previous research carried out in our laboratory with 'red' variety garlic, the one most widely cultivated in our region, showed that the radioinhibition process

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can extend the storage life when the bulbs are treated with 30 Gy of ^{60}Co gamma rays about 30 days after harvest. Less weight was lost in irradiated garlic bulbs than in non-irradiated ones during the storage period. The irradiated garlic bulbs underwent physiological losses in weight about 100% smaller than non-irradiated ones, between 210 and 270 days after harvest. From 210 days post harvest, the irradiated garlic bulbs showed a significant difference in the percentage of marketable bulbs as compared with non-irradiated bulbs. At the end of storage, 270 days post harvest, the irradiated garlic bulbs were about 80% marketable while the non-irradiated garlic bulbs were only about 35% marketable. These results prove the advantages of the irradiation treatment on extended storage of 'red' variety garlic bulbs. Therefore, the storage of garlic bulbs could be extended through critical marketing periods when this variety was not available for raw consumption (Croci & Curzio, 1983; Curzio *et al.*, 1983).

In spite of existing information about the commercial quality of irradiated garlic bulbs, little has been researched regarding the contents of the main chemical components of the bulbs during storage. Guo An-Xi *et al.* (1981) evaluated the contents of dry matter, soluble carbohydrates and vitamin C in irradiated garlic (doses under 500 Gy) up to 8 months' storage. The contents of dry matter and soluble carbohydrates did not differ from those of non-irradiated bulbs, while the content of vitamin C was greater in the irradiated bulbs towards the end of the storage period. Fernández & Arranz (1979) did not find any modifications in the dry matter content up to 11 months' storage with doses up to 300 Gy.

This study was conducted to investigate the effect of irradiation of 'red' variety garlic on some chemical parameters during the critical marketing periods. The contents of dry matter, water-soluble carbohydrates, ascorbic acid and enzymatic pyruvate, as a measure of flavour strength and the acidity of aqueous extracts, were determined.

MATERIALS AND METHODS

Materials

'Red' variety garlic bulbs, grown in the CORFO-Río Colorado zone, were employed in this study. They were harvested during early December and cured naturally in the field for 10 days. Afterwards, about 100 kg of bulbs were packed in bags of about 5 kg each. The bulbs were stored under warehouse conditions up to, and after, irradiation treatment.

Irradiation

Thirty days after harvest, half of the sample was irradiated at the facilities of the Comisión Nacional de Energía Atómica with a dose of 30 Gy of ^{60}Co gamma rays at the rate of 0·41 Gy/s, the dose uniformity ratio being 1·25. The other half of the sample was left as a control.

Chemical analyses

The chemical assays were carried out 210, 240 and 270 days after harvest. The cloves were randomly selected from random samples of marketable bulbs (neither spoilage nor external sprout were evident) and were analysed in triplicate. For evaluating the ascorbic acid content, 50 ± 1 g of fresh sample (wet weight), were used. The remaining determinations were carried out on samples of 10 ± 1 g.

The dry matter content was determined by drying the samples at 90 ± 2°C until a constant weight was obtained. The carbohydrates were extracted by homogenizing the sample with distilled water and they were estimated by the anthrone colorimetric method with glucose as standard (Yemm & Willis, 1954). The photometric assay with 2,6-dichlorophenolindophenol was used to evaluate the ascorbic acid content (Ruck, 1969); the extracts were obtained by homogenizing the tissue with oxalic acid. The acidity was determined from aqueous extracts by using a potentiometric measure. The flavour strength was evaluated in terms of enzymatic pyruvate content by difference between total pyruvate content and non-enzymatic pyruvate content. The total pyruvate content was measured by using 2,4-dinitrophenylhydrazine (Freeman & Mossadeghi, 1970). The same method was used to determine the non-enzymatic pyruvate content after inactivation of alliinase by immersion in liquid air (Freeman & Mossadeghi, 1971).

All results were expressed as mean $\pm$ standard error (SE) and were statistically analysed by analysis of variance by the F test (Snedecor, 1959).

RESULTS AND DISCUSSION

The contents of dry matter during the control period showed no significant differences between non-irradiated and irradiated bulbs. The dry matter contents varied between the beginning and the end of the control period as follows: 32·8–30·4 g/100 g for non-treated samples and 32·6–33·3 g/100 g for treated ones.

The acidity of aqueous extracts showed no significant differences between the treated and non-treated samples up to 240 days post harvest storage. At 270 days' storage the irradiated samples showed an average 5% excess of acidity over the non-irradiated samples. The pH values varied between the beginning and the end of the control period as follows: 6·5–6·2 for the non-irradiated samples and 6·3–5·9 for the irradiated samples.

The content of water-soluble carbohydrates in non-irradiated and irradiated bulbs is shown in Table 1. No significant differences were detected between non-treated and treated bulbs up to 240 days post harvest storage. At 270 days post harvest storage, a reduction was observed in the water-soluble carbohydrate content in irradiated bulbs. This reduction has not been reported for irradiated garlic bulbs, although a reduction has been found in onion bulbs (Baraldi, 1975). No explanation has been found to date regarding this behaviour.

Table 2 shows the contents of ascorbic acid in irradiated and non-irradiated garlic bulbs. The content was always greater in irradiated bulbs for the period considered. Between 210 and 240 days post harvest the content of ascorbic acid in irradiated samples was greater, in the order of 30%, while, at 270 days, it was only 14% greater. The results

TABLE 1
Effect of Gamma-irradiation on the Water-soluble Carbohydrate Content (g/100 g of Dry Weight) in Garlic Bulbs

Treatment	*Storage time post harvest (days)*		
	210	*240*	*270*
Non-irradiated	77·1 ± 3·7	84·3 ± 2·1	66·7 ± 1·1
Irradiated	90·6 ± 4·9	78·0 ± 4·1	38·1 ± 0·5**

Values are means of three replicates ±SE.
** Significant at $p < 0{\cdot}01$ according to F test.

TABLE 2
Effect of Gamma-irradiation on the Ascorbic Acid Content (mg/100 g of Dry Weight) in Garlic Bulbs

Treatment	*Storage time post harvest (days)*		
	210	*240*	*270*
Non-irradiated	45·7 ± 1·8	31·1 ± 0·3	30·7 ± 2·3
Irradiated	59·8 ± 6·8*	41·8 ± 0·7**	35·0 ± 0·7*

Values are means of three replicates ± SE.
* Significant at $p < 0{\cdot}05$ according to F test.
** Significant at $p < 0{\cdot}01$ according to F test.

agree with those reported by Guo An-Xi *et al.* (1981) and this finding has been attributed to a greater extractability of the vitamin by irradiation effect rather than to a net synthesis (Tobback, 1977).

The content of enzymatic pyruvate is shown in Table 3 for both treatments. The irradiated garlic showed a constant level of enzymatic pyruvate during the control period, while the non-irradiated garlic presented a significant reduction, of the order of 10%, at the end of the storage period. Watanabe & Tozaki (1967) found no differences in content and physico-chemical properties of the alliinase enzyme of irradiated garlic compared with non-irradiated garlic although research during storage was not carried out. Our results suggest that the radioinhibition process in garlic might benefit the flavour in terms of enzymatic pyruvate content. Investigations of the influence of irradiation on flavour by means of sensorial tests and their correlation with the enzymatic pyruvate content are in progress.

TABLE 3
Effect of Gamma-irradiation on the Enzymatic Pyruvate Content (μmoles/g of Dry Weight) in Garlic Bulbs

Treatment	*Storage time post harvest (days)*		
	210	*240*	*270*
Non-irradiated	233 ± 7·1	237 ± 8·4	214 ± 2·4
Irradiated	228 ± 6·6	228 ± 13·8	231 ± 3·0*

Values are means of three replicates ± SE.
* Significant at $p < 0{\cdot}05$ according to F test.

The results attained show that the radioinhibition process in 'red' variety garlic bulbs does not adversely affect the levels of the main chemical parameters when the product is stored for long periods for marketing purposes in non-traditional seasons.

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