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Effects of Gamma Irradiation and Temperature on Sugar and Vitamin C Changes in Five Indian Potato Cultivars During Storage

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ABSTRACT

The changes in sugar and vitamin C content of five potato cultivars subjected to gamma irradiation (100 Gy) to cause sprout inhibition were compared with nonirradiated control tubers during storage at 27–32°C (ambient temperature) and 15°C, and also with control tubers stored at 2–4°C—the commercial cold storage temperature. Reducing and nonreducing sugars increased during extended storage at all temperatures, the maximum increase occurring at 2–4°C. The proportion of nonreducing sugars was higher at 27–32°C, whereas at 2–4°C reducing sugars formed the greater proportion. Irradiation did not influence the pattern of sugar accumulation. Irradiated potatoes stored at 15°C for 6 months had lower sugar levels than control tubers stored at 2–4°C. During the first 2 months vitamin C levels were lower in irradiated potatoes stored at 15°C than in the controls stored at 2–4°C, but were subsequently higher. The suitability of tubers for processing into crisps and french fries was not affected by irradiation and storage at 15°C for 6 months.

INTRODUCTION

The potato is important nutritionally as a source of carbohydrates and ascorbic acid. The level of soluble sugars, particularly reducing sugars, in the tuber has a direct bearing on the processing qualities, as higher levels of sugars are the chief cause of undesirable browning in chips and french fries (Talburt & Smith, 1975).

It is well established that gamma irradiation at low doses of 75–100 Gy

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irreversibly inhibits sprouting of potatoes regardless of the post-irradiation storage temperature (Thomas, 1984). A great deal of information, which is often contradictory, has been reported on the effect of irradiation on sugar metabolism and ascorbic acid content of potatoes during storage (Matsuyama & Umeda, 1983; Thomas, 1984). Two types of increases in the sugar level of irradiated potatoes have been observed: (1) a temporary rise in both reducing and nonreducing sugars during the first 5–7 days after irradiation, which often returns to the normal level during further storage (Jaarma, 1958; Burton *et al.*, 1959; Baraldi *et al.*, 1972; Becker & Somogyi, 1977; Fiszer *et al.*, 1985); and (2) an increase on prolonged storage or senescent sweetening (Burton & Hannan, 1957; Sereno *et al.*, 1957; Burton *et al.*, 1959; Fiszer *et al.*, 1985).

Although some loss of vitamin C has been observed soon after irradiation (Salkova, 1957; Maltseva *et al.*, 1967) or during the early storage period following irradiation (Gounelle *et al.*, 1968), no significant differences between irradiated and nonirradiated potatoes were noted after prolonged storage (Salkova, 1957). Many other studies indicate no detrimental effect on ascorbic acid content as a consequence of irradiation and storage (Krylova, 1957; Panalkas & Pelletier, 1960; Woggen, 1963; Baraldi *et al.*, 1972; Winchester & Visser, 1975).

In India potatoes meant for household consumption are stored commercially for periods of 6–9 months in cold storage maintained at 2–4°C, relative humidity 90–95%. Cold storage results in increased accumulation of sugars in the tubers, although subsequent exposures to ambient temperatures for 7–8 days lowers the sugar level in most cultivars (Singh & Verma, 1979). Gamma irradiation at 100 Gy for sprout inhibition, followed by storage at 10 or 15°C, has been suggested as an alternative to cold storage (at 2–4°C) for table potatoes (Thomas *et al.*, 1979). It is important that irradiation does not increase sugar levels in potatoes, thus affecting their suitability for processing into crisps and french fries.

The studies reported here were undertaken to gain information on the changes in sugars and vitamin C content of some important potato cultivars grown in India which were subjected to gamma irradiation for sprout inhibition and stored at 27–32°C (ambient temperature) or at 15°C and to compare these changes with nonirradiated control tubers stored under identical conditions, and 2–4°C, for similar durations.

MATERIALS AND METHODS

The different potato cultivars used in these studies were drawn from a series of storage experiments, the details of which have been published elsewhere (Thomas *et al.*, 1979).

Potato tubers were irradiated at a dose rate of 4·55 Gy min^{-1} to a minimum absorbed dose of 100 Gy in a package irradiator in air at 25–26°C. The overdose ratio was 1·4.

For chemical analysis, ten tubers selected at random were deskinned with a hand peeler. Quarters from each tuber were cut longitudinally from bud to stem end, diced and mixed thoroughly. Ten grams of pulp in duplicate was extracted with 85% aqueous ethyl alcohol in a Soxhlet apparatus (Toshniwal, Madras, India) (AOAC, 1970) and reducing and nonreducing sugars (after inversion with HCl) were determined colorimetrically (Nelson, 1944). For vitamin C, 20 g pulp in duplicate was blended with 100 ml 3% metaphosphoric acid–acetic acid reagent and the amount present in the filtrate was estimated by visual titration against 2,6-dichlorophenol indophenol dye (AOAC, 1970).

RESULTS AND DISCUSSION

Table 1 summarises the changes in reducing and total sugars in irradiated and control tubers of five potato cultivars during storage at 27–32°C (ambient conditions), 15°C and 2–4°C. Under ambient conditions, reducing sugar levels either decreased or remained unchanged during the first 70 days, but at the end of 105 days the reducing sugar level increased in control tubers of cultivars *Kufri Chandramukhi* and *Kufri Kuber* and in irradiated tubers of *Kufri Kuber*, *Kufri Sheetman* and *Kufri Sindhuri*. Nonreducing sugars increased in all cultivars during storage; irradiated tubers exhibited similar or lower values except in *Kufri Sheetman*. Data on sugars for storage periods beyond 105 days could not be obtained at 27–32°C as tubers were spoiled on account of soft rot caused by *Erwinia* spp. The increased accumulation of nonreducing sugars observed at 27–32°C agrees with the findings reported for potatoes held in a farm store at 24·7–36·2°C (Verma *et al.*, 1974).

Storage at 15°C resulted in a gradual rise in both reducing and nonreducing sugars; irradiated samples exhibited comparatively higher levels than controls in cultivars *Kufri Chandramukhi*, *Kufri Kuber* and *Kufri Sheetman*. A comparison of the data at 27–32°C and 15°C for tubers stored for 105 days indicates a higher rate of sugar accumulation at 15°C. After 90 days of storage at 15°C, control tubers were shrivelled and unmarketable due to profuse sprouting and sprout growth (Thomas *et al.*, 1979).

Maximum increase in sugars was recorded in control tubers stored at 2–4°C, the proportion of reducing sugars being greater than nonreducing sugars. This is in agreement with the general observation that low temperatures enhance starch degradation with a concomitant rise in sugars, particularly reducing sugars (Talburt & Smith, 1975). We have not tested the levels of sugars in irradiated potatoes stored at 2–4°C since the radiation

TABLE 1
Reducing and Total Sugar Contents (% fresh weight) of Potatoes as Influenced by Storage Temperature and Irradiation

Storage period (days)	*27–32°C, relative humidity 60–80%*				*15°C, relative humidity 80–85%*				*2–4°C, relative humidity 90%*	
	Control		*Irradiated*		*Control*		*Irradiated*		*Control*	
	RS[a]	*TS*[b]	*RS*	*TS*	*RS*	*TS*	*RS*	*TS*	*RS*	*TS*
					Kufri Alankar					
0	0·54	0·69	—	—	0·54	0·69	—	—	0·54	0·69
30	0·30	0·64	0·25	0·70	0·45	0·83	0·42	0·76	1·03	1·67
70	0·27	1·00	0·21	1·17	0·53	0·96	0·34	0·53	0·71	1·44
105	—	—	0·38	1·02	0·62	1·26	0·69	1·23	0·93	1·72
180	—	—	—	—	1·30	2·70	1·35	2·70	2·03	3·68
					Kufri Chandramukhi					
0	0·38	0·49	—	—	0·38	0·49	—	—	0·38	0·49
30	0·22	0·45	0·27	0·49	0·39	0·75	0·39	0·85	0·45	0·96
70	0·21	0·87	0·33	0·94	0·44	0·82	0·78	1·56	—	—
105	0·51	1·11	0·28	0·96	0·46	1·38	0·62	1·17	1·94	3·63
140	—	—	—	—	1·15	1·74	0·77	1·31	1·60	2·47
180	—	—	—	—	1·14	2·20	1·28	2·38	1·77	2·96
					Kufri Kuber					
0	0·29	0·39	—	—	0·29	0·39	—	—	0·29	0·39
30	0·23	0·60	0·11	0·49	0·31	0·74	0·25	0·48	0·59	1·41
70	0·19	0·77	0·32	1·08	0·44	0·77	0·39	0·86	0·91	1·88
105	0·48	1·40	0·62	1·05	0·59	1·08	0·62	1·42	1·68	2·99
140	—	—	—	—	—	—	0·28	1·71	2·01	3·07
180	—	—	—	—	—	—	1·07	2·30	—	—
					Kufri Sheetman					
0	0·47	0·59	—	—	0·47	0·59	—	—	0·47	0·59
30	0·40	0·71	0·50	1·02	0·36	0·62	0·43	0·70	0·63	1·23
70	0·47	1·14	0·34	1·18	0·87	1·53	0·32	0·91	1·21	1·94
105	0·40	0·63	0·56	1·12	0·87	1·73	1·03	2·02	2·38	3·87
140	—	—	—	—	—	—	0·83	1·71	1·47	2·44
180	—	—	—	—	—	—	1·69	2·65	2·15	3·90
					Kufri Sindhuri					
0	0·22	0·36	—	—	0·22	0·36	—	—	0·22	0·36
30	0·22	0·45	0·28	0·63	0·79	1·43	0·40	0·78	0·64	1·22
70	0·41	1·08	0·35	0·65	—	—	—	—	0·81	1·64
105	0·29	0·76	0·37	0·79	0·95	1·53	0·53	1·20	1·13	2·28
140	—	—	—	—	—	—	1·59	2·76	1·21	2·53
180	—	—	—	—	—	—	1·27	2·71	1·82	3·71

[a] Reducing sugars. [b] Total sugars.

technology for sprout inhibition in potatoes does not normally include subsequent storage at 2–4°C. Thus a comparison of the sugar content of irradiated and control potatoes stored for similar durations at 15°C and 2–4°C, respectively, shows that sugar accumulation was lower in irradiated tubers at 15°C. These findings corroborate the results that sugar changes in 100-Gy irradiated Up-to-Date and Alpha potatoes during 6 months storage at 14°C were 50% lower than in nonirradiated tubers stored at 4–5°C (Eisenberg *et al.*, 1971).

In a preliminary test using irradiated and control *Kufri Chandramukhi* potatoes stored up to 180 days at 15°C and 2–4°C, respectively, and subsequently reconditioned at ambient temperature (27–32°C) for 7–8 days, we have observed that crisps and french fries made from irradiated tubers had better appearance, indicating their suitability for processing.

Immediately following irradiation, a 6–17% reduction in the vitamin C content of different potato cultivars was noted. However, these differences were not seen after 30 days storage (data not shown). A comparison of the vitamin C retention in all cultivars stored for 105 days at various temperatures indicates that vitamin C loss was greater at 2–4°C and maximum retention occurred at 27–32°C (Table 2). Panalkas and Pelletier (1960) found that storage of potatoes at 20°C resulted in higher ascorbic acid content than storage at 4·4°C and the ascorbic acid content of tubers stored at 4·4°C increased by placing them at a higher temperature.

TABLE 2

Effect of Irradiation and Storage Temperature on Vitamin C Retention in Potatoes (expressed as per cent of initial content)

Cultivar	*Storage period (days)*	*27–32°C, relative humidity 60–80%*		*15°C, relative humidity 80–85%*		*2–4°C, relative humidity 90%*
		Control	*Irradiated*	*Control*	*Irradiated*	*Control*
Kufri Alankar	105	89·3	76·4	62·0	79·4	59·5
(9·60)[a]	180	—	—	—	72·5	52·5
Kufri Chandramukhi	105	63·7	62·1	63·7	63·7	46·9
(14·20)[a]	180	—	—	—	54·1	49·1
Kufri Kuber	105	71·0	65·0	67·0	77·1	50·4
(11·80)[a]	180	—	—	—	85·8	57·0
Kufri Sheetman	105	86·3	86·3	57·5	80·4	57·5
(8·28)[a]	180	—	—	—	95·7	63·8
Kufri Sindhuri	105	96·7	90·4	61·0	71·0	53·0
(10·10)[a]	180	—	—	—	66·6	54·7

[a] Values in parentheses are the initial content of vitamin C expressed as mg % fresh weight.

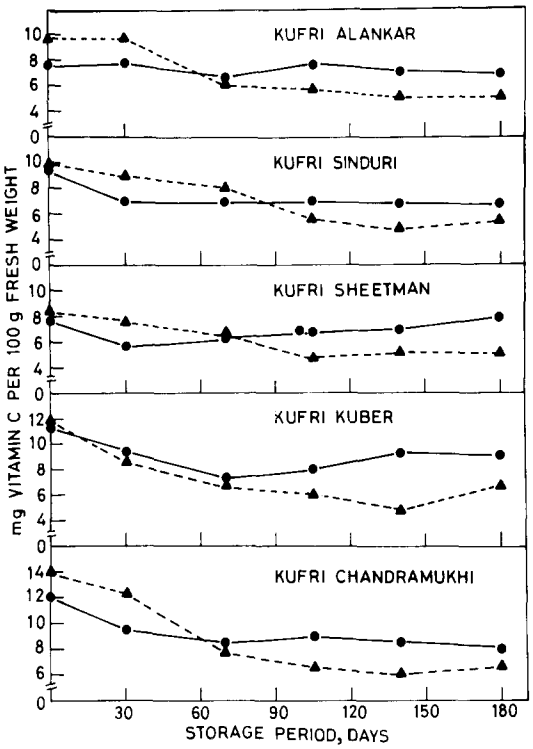

Fig. 1. Changes in vitamin C content of different potato cultivars during storage. ●, Irradiated (100 Gy) stored at 15°C; ▲, control stored at 2–4°C.

The patterns of vitamin C changes in irradiated and control potatoes stored at 15°C and 2–4°C, respectively, are shown in Fig. 1. In all cultivars except *Kufri Kuber*, irradiated tubers stored at 15°C showed lower vitamin C levels during the early period of storage. However, this trend was reversed during further storage and at the end of 180 days irradiated tubers stored at 15°C recorded higher levels than control tubers stored at 2–4°C. Studies conducted in Israel have shown that during a storage time of up to 6 months vitamin C was 10–25% greater in irradiated potatoes held at 14°C than nonirradiated tubers held at 4°C (Eisenberg *et al.*, 1971).

In conclusion, results of the present studies showed that losses in vitamin C were lower in five Indian potato cultivars irradiated for sprout control and subsequently stored at 15°C than in nonirradiated tubers stored at the commercial cold storage temperature of 2–4°C. Irradiated potatoes accumulated less sugars than did cold-stored tubers and were suitable for making crisps and french fries.

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