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Prolonged low-temperature storage of eggplants in polyethylene bags

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Abstract

The quality of eggplant fruit (*Solanum melongena* L.) during prolonged storage may be impaired by the susceptibility of the fruits to deterioration and chilling injury at low temperature (<10°C). This work shows that eggplants harvested during winter (December–January) were more susceptible to chilling injury than those harvested during spring (March–April). Storing disinfected eggplant fruits inside an unperforated polyethylene (PE) bag enabled them to be stored at 8°C for more than three weeks without sustaining any chilling injury, whereas disinfected but unbagged control fruits showed severe chilling injury. The cooling rate of the bag-packed fruit was significantly slower than that of the control fruit, and the temperature of the fruit packed in bags was always maintained at 0.5–1.0°C above the storage temperature.

Keywords: Eggplant; Postharvest; Storage; Polyethylene bag; Low temperature

1. Introduction

It is well known that keeping fruits and vegetables at low temperature from harvest until produce reaches consumers is an effective means of maintaining their quality and nutritional value. However, most fruits and vegetables originating from tropical and subtropical areas are chilling sensitive and readily suffer chilling injury (CI) after being kept at a temperature lower than the critical point for a certain period (Saltveit and Morris, 1990).

The eggplant, *Solanum melongena* L. is a cultivated plant of the nightshade family (*Solanaceae*). Its fruit is a non-climacteric large berry, purple or violet in colour, and is an important market vegetable, especially in Asia and the Mediterranean

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countries (Nothmann, 1986). Since eggplant is chilling-sensitive, it cannot be stored at temperatures below 10°C to extend shelf life (Nothmann, 1986). Surface pitting of the peel and browning of seeds and vascular bundles occur in eggplants after 4–5 days at 1°C. The symptoms which become extremely severe when the fruit is transferred to 20°C, are associated with rapid decay development, mostly on the calyx (Abe et al., 1974). Recently, we reported that dipping eggplant calyx in a solution of fungicide and plant growth regulator retarded calyx senescence and controlled decay for more than two weeks of storage at 12°C (Temkin-Gorodeiski et al., 1993). Polymeric films influence the development of CI in fresh produce by creating a modified atmosphere around the commodity and by slowing water loss (Forney and Lipton, 1990). Packaging of eggplant in high-density PE appeared to be a beneficial supplement to refrigeration, depending upon the cultivar (Mohammed and Sealy, 1986). Enclosing sweet bell peppers in PE bags or PVC shrink film reduced CI during 18 of days storage at 4–6°C (Gorini et al., 1977). We report here on the effect of PE-bag packaging on the quality of disinfected eggplant fruit stored at low temperature.

2. Materials and methods

Fruit treatments and storage

Large (300–400 g) eggplant fruits (*Solanum melongena* L. cv. 'Classic') were obtained from unheated greenhouses in southern Israel at the beginning (winter, December–January) and end (spring, March–April) of the growing season. This cultivar ('Classic') cannot be stored for a prolonged time at temperatures less than 12°C (Hardenburg et al., 1986). The selected fruits were damage free (export grade 'A') and were treated within 24 h of harvesting by dipping their calyces for 30 s in 0.09% active ingredient (a.i.) prochloraz (Prochloraz EC 45%, Schering Ltd.) mixed with 0.02% (a.i) naphthalene acetic acid (NAA) (Aperdex-S, 40%, Rhizopon, The Netherlands) (Temkin-Gorodeiski et al., 1993). After treatment, fruits were dried in air for 30 min prior to packaging. Twelve to fourteen eggplant fruits were packed in two layers in an unperforated low-density PE bag (30 μm thick, 65 × 70 cm) and each layer was enclosed in four sheets of tissue paper in order to absorb any remaining water droplets (Fallik et al., 1993). Each bag was then folded shut and placed individually in a shipping carton (bag packed — BP). Eggplants were stored at 6, 8 and 12°C and relative humidity (RH) of 87–90% (measured by thermohygrograph, Casella, London) for 2, 5, 10, 16 and 20 days. After storage, fruits were removed from the PE bags and transferred to a storage room for 3 days of shelf-life simulation at 17°C and RH 80–85%. Treated fruits packed between two sheets of tissue paper, without PE bags, in the shipping carton (control packed — CP) served as controls.

Fruit quality parameters

After 2, 5, 10 and 16 days storage of the fruit at various temperatures and 3 days at 17°C, internal and external CI symptoms were evaluated. After 20 days storage at various temperatures and 3 days at 17°C, the quality of the fruit was evaluated as follows: weight loss was expressed as a percentage of the initial weight; fruit firmness was determined with a compression tester, using a 2-kg weight for 15 s and measuring residual deformation in mm. Fruit was categorised as very firm, firm or soft, according to whether it had a deformation $\leq$1.5, 1.6–3.0, or >3.0 mm. A fruit was scored as decayed or affected by CI if mycelia or dark round pits, respectively, appeared on the calyx or peel. Decay and CI incidence were expressed as a percentage of the total amount of fruit observed.

Temperature monitoring and relative humidity measurement

The temperatures of PE-BP or CP fruit stored at three different temperatures were monitored for the first 48 h and then every 24 h until the end of the storage period, by a Data Trapper 1803 (YM Electronic Industries, Bene Beraq, Israel). Temperature probes (PT-100) were placed into eggplant flesh (3 cm deep) in each of two shipping cartons from each treatment. The relative humidity inside the bag was measured by a Lambrecht hygrometer (Germany) which was placed on top of the tissue paper.

The results presented are the averages of two experiments which were conducted in each season. Each treatment consisted of three replicate cartons. Results were analyzed as a completely randomized factorial design. Significance was evaluated by Duncan's multiple range test.

3. Results

The effect of the PE bag on the cooling rate of fruit

The cooling of the BP fruit was significantly slower than that of the CP fruits both at the beginning and at the end of the season (Fig. 1). The temperature of BP fruit always stabilized 0.5–1.0°C above each target storage temperature.

The initial temperature of winter fruit was about 15°C. CP fruits which were to be stored at 6, 8 and 12°C reached these temperatures after 16, 12 and 12 h, respectively (Fig 1A). Eggplants stored in PE bags reached 7, 9 and 13°C after 28, 28 and 12 h, respectively. In the case of spring-grown eggplants the initial temperature was 24°C. CP fruits to be stored at 6, 8 and 12°C reached those temperatures after 24, 24 and 20 h, respectively. BP fruit reached 7, 9 and 13°C after 36, 28 and 28 h, respectively (Fig. 1B).

The influence of storage in PE bags on the development of chilling injury

Storage of the winter fruit at 6 and 8°C resulted in rapid development of CI compared with spring-grown eggplants (Fig. 2). The most obvious evidence of CI was the appearance of surface pitting on the calyx and on the peel. However, internal browning was also observed as a symptom of CI (data not shown). The PE bag (BP) significantly reduced CI development in both winter- and spring-harvested fruit. After two days of storage at 6°C, the CI incidence of CP winter eggplant was 13%; there followed a significant increase of CI during storage (Fig. 2A). No CI was found on BP fruit stored at 6°C for up to 5 days. From the 10th day of storage at 6°C and onward, CI was significantly lower in BP fruit than in CP fruit. The CI on

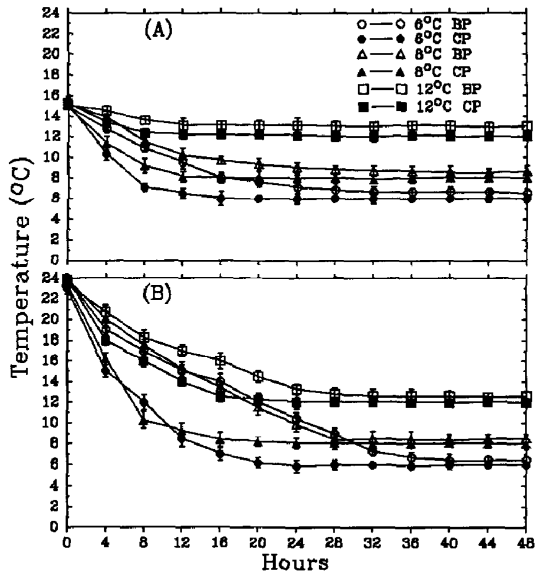

Fig. 1. The effect of PE bag packaging (BP) on fruit temperature during the first 48 h of storage compared with control-packed fruit (CP). (A) fruit harvested in winter; and (B) fruit harvested in spring. Bars indicate S.E.

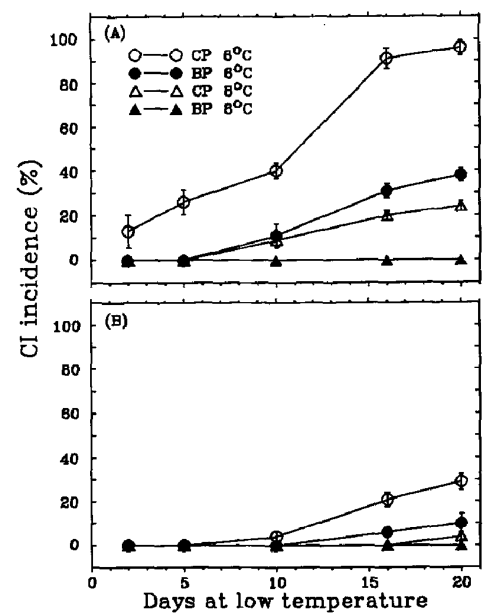

Fig. 2. Development of chilling injury on fruit packed without (CP), or with (BP) PE bag and stored at 6 or 8°C. Fruits were evaluated after 3 days at 17°C following each removal from storage. (A) winter-; and (B) spring-harvested fruit. Bars indicate S.E.

CP winter fruit stored at 8°C was obvious only after 10 days of storage, but the CI incidence was significantly lower than in CP fruit stored at 6°C (Fig. 2A). No CI was observed on BP fruit stored at 8°C.

CP fruit harvested in spring and stored at 6°C developed CI after 10 days of storage, while BP fruit stored at 6°C developed slight CI only after 16 days (Fig. 2B). Chilling injury in spring-harvested fruit was less severe than in winter-harvested fruit, and was found mainly on the calyx. No CI developed on either CP or BP fruit stored at 8°C, even after 20 days of storage and an additional 3 days of holding at 17°C (Fig. 2B).

In most cases, surface pitting was associated with decay development mainly caused by *Alternaria alternata*.

The influence of PE bags on the quality of fruit stored for 20 days at various temperatures

After 20 days of storage at several different temperatures and an additional 3 days at 17°C, the BP fruit quality as evaluated by decay incidence, weight loss and firmness, was significantly higher than that of CP fruit (Table 1). The quality of CP fruit stored at 8°C and evaluated according to weight loss and firmness was significantly higher than that of CP fruit stored at 12°C. However, no significant differences were observed between BP fruit stored at 8°C and 12°C, respectively (Table 1).

The relative humidity inside the PE bag during 20 days of storage at three temperatures, and before transferring the fruit to shelf life simulation for three days, averaged 93%. The CO_2 and O_2 levels inside the bags averaged 1.2% and 19.7%, respectively.

Table 1

The influence of packing in PE bag (BP) on quality of fruit (decay, weight loss and firmness) stored for 20 days at various temperatures and an additional 3 days at 17°C. (A) winter and (B) spring eggplant fruit

Temperature (°C) Packaging:	Decay (%)		Weight loss (%)		Firmness [a]	
	CP [b]	BP [c]	CP	BP	CP	BP
(A) Winter fruit						
6	14.0 A* [z]	6.0 A	4.8 A*	2.9 A	3.3 B*	2.1 A
8	5.0 B*	0.5 B	3.0 B*	1.8 B	2.7 C*	1.4 B
12	4.0 B*	0.0 B	4.9 A*	1.8 B	3.5 A*	1.5 B
(B) Spring fruit						
6	6.0 A	6.0 A	3.8 B*	1.9 A	2.6 B*	1.3 A
8	8.0 B	0.0 B	3.0 C*	1.6 B	1.4 C*	1.1 A
12	12.0 B	4.0 B	4.5 A*	2.0 A	3.1 A*	1.3 A

[a] Firmness: ≤1.5 mm = very firm; 1.6–3.0 mm = firm; ≥3.0 = soft.

[b] Control-packed fruit (without PE bag).

[c] Bag-packed fruit (in PE bag).

[z] Means within a column followed by different capital letters are significantly different among temperatures, according to Duncan's multiple range test at $P \leq 0.05$. Means within a row followed by an asterisk are significantly different between unpacked or packed fruit ($P \leq 0.05$).

4. Discussion

Eggplant fruits show the typical symptoms of chilling injury when they are stored at low, non-freezing temperatures. Differences in storage recommendations for eggplant fruit are in part related to different cultivars used (Aubert and Pochard, 1981) and to seasonal effects (Abe et al., 1976). Our study showed that storing disinfected eggplant fruit for a prolonged period inside unperforated PE bags delayed or inhibited the development of chilling injury. Film packaging of many fruits has been reported to reduce CI. Hobson (1981) reported that CI can be reduced in breaker-stage tomatoes by keeping them in PE bags. Wrapped melons exhibited 30% less CI symptoms than non-wrapped fruit stored at 2.5°C (Rij and Ross, 1988). Recently Meir et al. (1993) reported that packing of red sweet peppers in perforated PE bags enabled the storage temperature to be reduced to 3°C without CI. The reduction of CI is probably due to the prevention of water loss from the fruit, or to the maintenance of high RH inside the individual bags (Ben-Yehoshua, 1985). It is also possible that the lower CI of the fruit inside the bags is due to the slower fall of the its temperature, as compared with that of fruit packed without PE bags. The choice of growing season affected the susceptibility of the fruit to CI. Eggplants grown at high temperatures in southern Israel during October and November and harvested during early winter were more sensitive to low-temperature storage than fruit harvested during the early spring which had been exposed to low temperatures during growth. Warshavski et al. (1973) found a similar correlation between the growing season and CI in cv. 'Black Beauty' in Israel. The sensitivity of tomato fruit to chilling varies with the growing season and harvesting date (Abdel-Maksoud et al., 1974). It has also been reported that genetic diversity of chilling sensitivity within a species can influence chilling injury (Brecht et al., 1984).

Storing disinfected eggplant fruit inside a PE bag, at a relatively low temperature (8°C) could extend the storability and shelf life of this fruit. This finding could be beneficial when eggplant fruits are transported and marketed together with other commodities which are not chilling sensitive, or which require storage at low temperatures. The simplicity of this method of packaging, combined with low temperature storage, could considerably expand the scope for exporting high-quality fruit to distant markets.

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