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Effects of Adenosine Triphosphate on Browning and Quality of Harvested Litchi Fruit

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Abstract: Pericarp browning and loss in pulp quality are major problems of harvested litchi fruit. The effects of adenosine triphosphate (ATP) on the browning and quality of harvested litchi fruit were investigated. Litchi fruit were dipped into a solution of 0 or 1.0 mM ATP for 3 min and then stored for 5 days at 25°C and 80-90% relative humidity. ATP treatment effectively reduced skin browning, inhibited disease development and delayed increase in membrane permeability. Furthermore, the fruit treated with 1 mM ATP had higher concentrations of total soluble solids, titratable acidity and ascorbic acid of the flesh than the non-ATP-treated fruit, particularly in ascorbic acid. Application of ATP exhibited potential for browning control and quality maintenance of harvested litchi fruit.

Key words: *Litchi chinensis*, ATP, bowning, quality, fruit

Introduction

Litchi (*Litchi chinensis* Sonn.) is a subtropical to tropical fruit of high commercial value in the international market due to its sweet, acidic and crisp pulp (Tindall, 1994; Nakasone and Paull, 1998). However, the fruit after harvest are very perishable and rapidly lose quality (Nip, 1988; Ray, 1998). Pericarp browning and loss in flesh quality are major problems of harvested litchi fruit.

Litchi pericarp browning is generally thought to be the responsible for breakdown of cellular membranes, leading to loss of compartmentation between enzymes and substrates, which produced brown by-products (Huang *et al*., 1990; Jiang and Fu, 1998; Jiang, 2000). Jiang and Chen (1995a, b) reported that membrane permeability increased in aging litchi fruit while membrane fluidity deceased with increasing storage. Thus, the membrane deterioration of litchi fruit after harvest may lead to the browning.

Investigations showed that energy lack was associated with membrane deterioration during browning or senescence tissues of harvested horticultural crops (Saquet *et al*., 2000; Veltman *et al*., 2003). Trippi and Paulin (1984) found that increases in membrane permeability and proteolysis during carnation flower senescence in association with low ATP production. Duan *et al*. (2004) reported that membrane permeability increased while levels of ATP, adenosine diphosphate (ADP) and Adenylate Energy Charge (AEC) decreased during browning of litchi fruits. A direct relation between energy metabolism and membrane integrity was demonstrated in potato cell cultures by Rawyler *et al*. (1999)

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who found that potato cells, subjected to anoxia, showed an ATP synthesis threshold, below which membrane lipids hydrolysed. Investigations suggested that ATP might influence cellular decompartmentation, due to changes in membrane lipids of fatty acids, which may lead to altered biophysical or biochemical membrane properties (Marangoni *et al*., 1996; Harwood, 1988). Thus, a lack of energy supply may contribute to browning of harvested litchi fruit.

There are no published data about the role of ATP in harvested litchi fruit during storage. The objective of this study was to investigate the effects of ATP on browning of harvested litchi fruit in association with membrane integrity, disease development and sensory traits.

Materials and Methods

Plant Materials and Treatments

Fruits of litchi (*Litchi chinensis* Sonn. cv. Huaizhi) at an 80% mature stage were obtained from a commercial orchard in Guangzhou, China. Fruit were selected for uniformity of shape and colour and blemished or diseased fruit were discarded. The fruit were dipped for 3 min in a solution of 0.1% TBZ with 0 or 1 mM ATP and air-dried for 2 h at 25°C. After treatments, fruit were packed into 0.02 mm polyethylene bags (30 fruits/bag) and then stored at 25°C and 80-90% relative humidity.

Skin Browning Measurement

Skin appearance was assessed by measuring the extent of the total browned area on each fruit pericarp of 90 fruits, using the following scale (Jiang and Chen, 1995a): 1, no browning (excellent quality); 2, slight browning; 3, <1/4 browning; 4, 1/4-1/2 browning; 5, >1/2 browning (poor quality). The browning index was calculated as Σ (browning scale × percentage of corresponding fruit within each class). Fruit at higher than 3.0 was considered unacceptable for marketing. The subjective evaluation of skin browning index was correlated well with the objective determination of the value of absorbance at 410 nm of the skin extract (Jiang, 2000).

Disease Incidence Evaluation

The development of disease resulting from natural infection was monitored by randomly collecting 90 fruits and then recorded as the percentage of fungal growth or bacterial lesions on the surface.

Measurement of Membrane Permeability

Membrane permeability, expressed by relative electrolyte leakage rate, was determined by the method of Jiang and Chen (1995a). Discs were removed with a cork borer (10 nm in diameter) from the equatorial region of 30 fruits. Thirty discs were rinsed twice and incubated in 25 mL of 0.3 M mannitol solution at 25°C, followed by shaking for 30 min. Electrolyte leakage was determined with a conductivity meter (Model DDS-11A, Shanghai Scientific Instruments). Total electrolyte leakage was determined after boiling another batch of 30 discs for 15 min and cooling to 25°C (total electrolytes). Relative leakage was expressed as a percentage of total electrolyte leakage.

Concentrations of Total Soluble Solids, Titratable Acidity and Ascorbic Acid

Total soluble solids, titratable acidity and ascorbic acid of control and ATP-treated fruit were analysed during postharvest life evaluation. Pulp (20 g) from 15 fruits were homogenised in a grinder and the supernatant phase was collected to analyze concentrations of total soluble solids, titratable acidity and ascorbic acid. Total soluble solids were assayed by using a hand refractometer (J1-3A, Guangdong Scientific Instruments); titratable acidity as % citric acid determined by titration with 0.1 M NaOH and ascorbic acid by 2,6-dichlorophenolindophenol, respectively.

Data Handling

Experiments were arranged in a completely randomized design. There were three replicates. Data were tested by the analysis of variance using SPSS version 7.5. Least Significance Differences (LSDs) were calculated to compare significant effects at the 5% level.

Results and Discussion

Effects of ATP on Peel Browning and Disease Development

Litchi fruit rapidly deteriorated after harvest due to the browning and decay (Huang and Scott, 1985; Johnson and Sangchote, 1994; Ray, 1998). Skin browning index increased markedly with storage time, while disease developed rapidly (Fig. 1 and 2). Dipping litchi fruit into 1 mM ATP solution reduced browning index and disease development during storage. Similar results were reported by Duan *et al.* (2004) who found that reduced skin browning of litchi fruit after pure oxygen treatment was associated with higher level of energy status of peel tissues. In this study, as ATP concentrations used increased, there was not enhanced effect of the browning inhibition (data not shown). Thus, the best concentration of ATP used requires further investigation.

Effects of ATP on Membrane Permeability

Browning of plant tissues was partly caused by membrane deterioration (Toivonen, 1992). Membrane permeability of litchi fruit, which was correlated negatively with membrane integrity (Marangoni, 1996), gradually increased during storage. The fruit dipped into 1 mM ATP solution had a lower leakage rate in association with reduced browning index, compared with the control fruit (Fig. 1 and 3). This investigation showed that application of exogenous ATP relatively maintained membrane integrity, which was consistent with Eilam (1965) who suggested that energy was essential for maintenance of membrane integrity. Saquet *et al.* (2001) reported that the flesh browning of Conference pears was associated with lower ATP concentrations in the fruit tissues, which might be due to loss in membrane integrity. Therefore, it could be suggested that the reduction of litchi fruit skin browning by ATP treatment could be accounted for maintenance of membrane integrity.

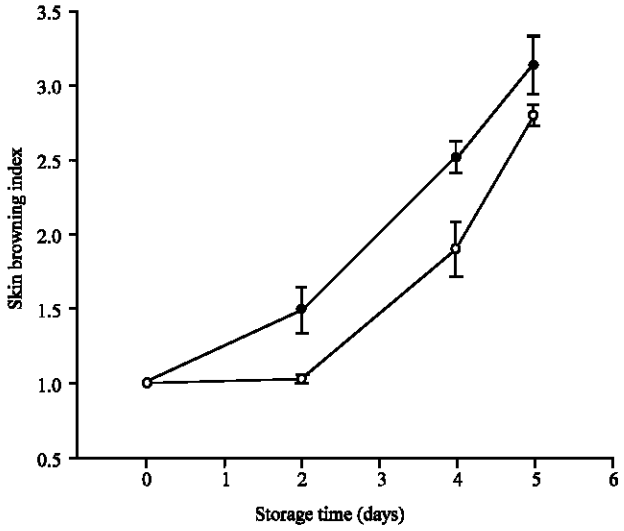

Fig. 1: Effect of ATP on browning index of litchi fruit. Fruit were treated with 0 (●) or 1 mM ATP (o) and stored for 5 days. Each value was the average for three replicate determinations. Vertical bars indicated the standard errors where they exceeded the symbol size

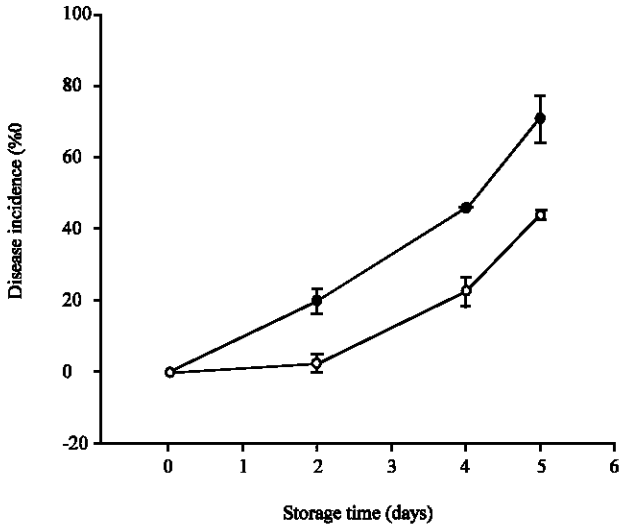

Fig. 2: Effect of ATP on disease incidence of litchi fruit. Fruit were treated with 0 (●) or 1 mM ATP (o) and stored for 5 days. Each value was the average for three replicate determinations. Vertical bars indicated the standard errors where they exceeded the symbol size

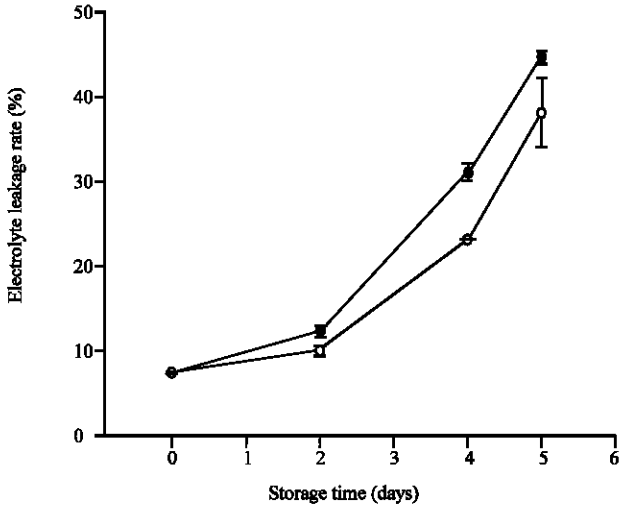

Fig. 3: Effect of ATP on electrolyte leakage rate of litchi fruit. Fruit were treated with 0 (●) or 1 mM ATP (o) and stored for 5 days. Each value was the average for three replicate determinations. Vertical bars indicated the standard errors where they exceeded the symbol size

Effects of ATP on Total Soluble Solids, Titratable Acidity and Ascorbic Acid

Total soluble solids, titratable acidity and ascorbic acid are important factors in assessing flavour and nutritive quality of litchi fruit (Jiang and Fu, 1998). As shown in Table 1, the concentrations of total soluble solids, titratable acidity and ascorbic acid of litchi flesh decreased after 4 and 5 days of storage, possibly due to an enhanced respiration and oxidation activities (Peng, 1998). Compared with the control, the fruit treated with 1 mM ATP had higher concentrations of total soluble solids,

Table 1: Effects of ATP treatment on contents of total soluble solids, titratable acidity and ascorbic acid of litchi fruit after 4 and 5 days of storage

	Storage time (days)			
	4		5	
Parameters	Control	Treatment	Control	Treatment
Total soluble solids (%)	17.03a	17.07a	15.90b	16.75a
Ascorbic acid (mg 100 g^{-1})	23.06a	23.33a	18.40b	22.39a
Total titratable acidity (%)	0.098a	0.101a	0.093a	0.096a

Means within cloums followed by some latter(s) are not significantly different at 5% level

titratable acidity and ascorbic acid after 5 days of storage, particularly in the concentration of ascorbic acid (Table 1). Saquet *et al.* (2001) and Veltman *et al.* (2003) suggested that brown core initiation in Conference pears might be a result of a limited availability of energy and antioxidants, with low ascorbic acid level and ATP production. The effectiveness of exogenous ATP treatment on the browning of litchi fruit may be due to the enhancement of antioxidants, but this needs further investigation.

In conclusion, treatment with 1 mM ATP effectively reduced skin browning, disease development and membrane permeability and maintained eating quality of litchi fruit, particularly in the ascorbic acid level. However, further investigation into the effect of the ATP treatment on the fruit could be needed during storage at low temperature because the low temperature storage is used widely in commercial situations.

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