

<b><i>DESCRIPTION:</i></b>	<b>Susceptibility to and Control of Skin Browning in 'Bartlett' Pears</b>
<b><i>PROJECT LEADER:</i></b>	<b>Beth Mitcham- UC Davis</b>
<b><i>2002 FUNDING:</i></b>	<b>\$28,406</b>
<b><i>FUNDING SOURCE:</i></b>	<b>California Pear Advisory Board</b>



# **Susceptibility to and Control of Skin Browning in ‘Bartlett’ Pears**

Report to the California Pear Advisory Board

December 2002

Elizabeth Mitcham, Xuqiao Feng and Bill Biasi

Department of Pomology, UC Davis

## **Summary**

Commercial and experimental coatings and antioxidants with potential to reduce skin browning of pears have been evaluated. Treatment with 0.2 % diphenylamine (DPA) or 0.3% ethoxyquin reduced skin browning on ‘Bartlett’ pears induced by vibration, rolling or scuffing. However, this effect only lasted for about 5 days when treated pears were stored at 32°F. In practice, pears would have to be treated and packed shortly before transport to achieve a reduction in skin browning. DPA and ethoxyquin did not reduce skin browning on pears induced by handling at 68°F after treatment. It is suggested that tight-fill packaging and use of DPA or ethoxyquin would best reduce skin browning. Treatment with 300 ppb 1-MCP decreased the sensitivity of pears to skin browning induced by hand-handling during shelf life at 68°F after storage at 30°F for 1, 2 or 3 months. This effect decreased with time during storage. Treatment with 1-MCP delayed fruit softening and the peak in respiration and ethylene production. The data suggest that 1-MCP is a possible candidate for control of skin browning and fruit softening during storage.

Experiments with ‘Bartlett’ pears harvested from different growing locations and on different dates within a location showed that browning potential was mainly related to fruit firmness. Fruit with higher firmness were less sensitive to browning. Fruit firmness is a useful indicator to predict fruit sensitivity to browning caused by mechanical injury. For size 110 fruit, when firmness was greater than 17 lbs, the fruit had little susceptibility to skin browning. The color intensity from the polyphenol oxidase (PPO) and total phenolics rapid tests were strongly correlated with browning of the pear skin and with actual PPO activity and total phenolics levels. These results further established that these rapid tests can be good indicators to predict the browning potential of pears.

Keywords: phenolics, coatings, antioxidants, skin browning, vibration damage

Commodity: ‘Bartlett’ pears

## **1. Introduction**

In 2001, we characterized the skin browning potential of pears from various sources and evaluated commercial and experimental coatings and antioxidants for their potential to reduce skin browning. Fruit firmness was found to be closely related to browning potential. In addition, we began to develop a rapid test to determine the browning susceptibility of pear fruit.

In the present research, commercially available and experimental coatings and antioxidants were tested for their potential to reduce skin browning. The effect of 1-MCP on pear browning was re-evaluated and confirmed. The browning potential of pears from various sources was characterized in relationship to fruit firmness. A method based on fruit firmness was developed to predict skin browning potential. A rapid test procedure which could be used in practice to determine fruit sensitivity to browning was also established.

## **2. Objectives**

1. Develop a method to control skin browning caused by mechanical injury using antioxidants or coatings.
2. Develop a rapid test method to determine the susceptibility to skin browning of pear fruit, and further characterize the relationship between fruit firmness and susceptibility to skin browning.

## **3. Materials and Methods**

**Objective 1:** Develop a method to control skin browning caused by mechanical injury using antioxidants or coating.

On the basis of the results of last year, the effects of treatments with various coatings, antioxidants or 1-MCP have been further explored by adjusting the proportion of various components and looking at different combinations of materials to achieve satisfactory browning control. Commercial handling of pears was simulated according to the standard of the pear industry in this aspect of the research to guarantee commercial applicability. A vibration-measurement device was used to accurately measure the vibration level so that uniform vibration treatments could be inflicted among different experimental lots. For the most effective treatments, the effect of time in storage on treatment efficacy was evaluated during storage at 32°F or at 68°F for up to 9 days.

### **A. Fruit Materials**

Commercially packed boxes of size 110 'Bartlett' pears were collected during the commercial harvest season from local packinghouses in Lake County. Pears were transported on the day of harvest to the Pomology Postharvest Laboratory and stored at 32°F until use.

## B. Skin browning induction and evaluation

This year, a vibration-measurement device was established to accurately measure the vibration level so that uniform vibration treatments could be inflicted among different experimental lots. The vibration table was developed by David Slaughter and Jim Thompson of the Dept. of Biological and Agricultural Engineering, UC Davis. As shown in Figure 1, vibration on the support plane was created by the vibration generator. Vibration intensity was controlled by adjusting the DC speed controller (model 4Z226E, Dayton Electric MFG.CO. Nilsbs, IL) The

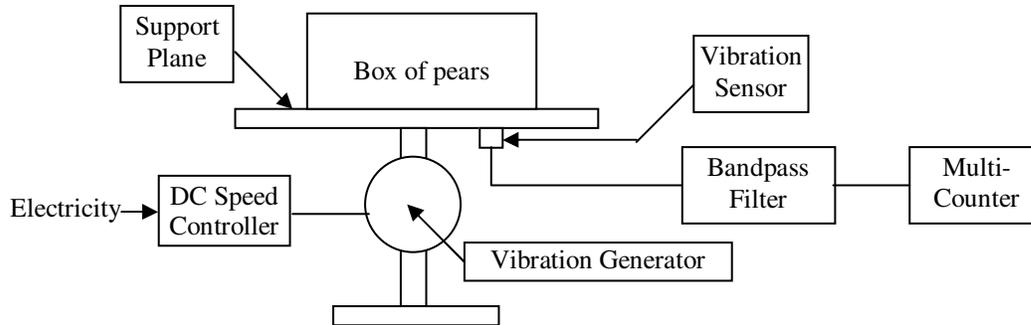


Figure 1. Vibration device for inducing skin browning on pears.

signal of vibration intensity was detected by a vibration sensor and transferred to a AF 601 bandpass filter and the vibration frequency was monitored by a multi-counter (John Fluke MFG.CO.INC, Everett, WA). Required vibration was achieved by adjusting the DC speed controller.

The vibration was set at 3.5-4 Hz with 1.1 G for 0.5 hours at 32°F. This was a simulation of mechanical injury of pears caused by truck transportation as determined by David Slaughter and Jim Thompson. Skin browning was judged by both the surface area browned and by the brown color intensity in this area. Browning area was subjectively recorded as a percentage of the fruit surface and brown color intensity was subjectively recorded on a 1-to-5 scale, where 1 = light brown and 5 = very dark brown. The amount and severity of pear skin browning was expressed by an index, which was calculated by the following formula:

$$\text{Skin browning index} = [(A \times 1 + B \times 2 + C \times 3 + D \times 4 + E \times 5) \times 0.75 + (F \times 0.25)] / \text{Total \# Fruit}$$

A = # pears with <1% brown area

B = # pears with 1-2% brown area

C = # pears with 3-5% brown area

D = # pears with 6-10% brown area

E = # pears with >10% brown area

F = total value of brown color intensity for all pears evaluated

Rolling, scuffing and hand-handling methods were developed to judge treatment efficacy. The rolling method was rolling the pears individually twice down a 6 foot long x 4.5 inch wide x 3 inch high wooden slot, held at a 25° angle with the ground (Figure 2). The surface of the slot was lined with medium grit emery cloth. After rolling, the pears were held at 68°F and skin browning was evaluated the next day.

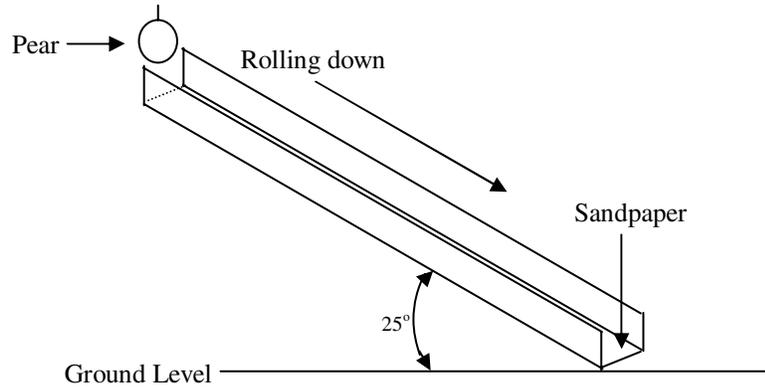


Figure 2. Rolling device for inducing skin browning on pears.

Scuffing was done by dragging the fruit once for 20 inches over a coarse wooden surface with a uniform force. The skin browning induced by scuffing was evaluated 10 minutes after induction. Hand-handling was done by rubbing the surface of each fruit 10 times uniformly with two hands.

This was to simulate skin browning potentially caused by consumers when the fruit are displayed for sale in the market. Skin browning was usually evaluated 1 hour after the induction because skin browning induced on firm pears by this method required some time to be visible (Table 1).

Except for skin browning induced by scuffing, the above-mentioned browning index was used to indicate the magnitude. Skin browning induced by scuffing on pears was evaluated by the brown color intensity and subjectively recorded on a 1-to-5 scale, where 1 = light brown and 5 = very dark brown. A color index, the arithmetic mean of the color intensity for all pears, was used to express the magnitude of skin browning induced by scuffing

Table 1. Methods of skin browning induction and evaluation for effective treatments

Browning-induction method	Storage temperature after induction	Time after induction for browning examination	No. of pears evaluated
Vibration	32°F	1 day	3 boxes
Scuffing	32°F	10 minutes	30 pears
Hand-handling	68°F	1 hour	30 pears

### **C. Treatment with Coatings and Antioxidants**

For each treatment, 3 boxes of pears were unpacked and dipped into a solution containing either the coating or an antioxidant for 5 minutes. The treated pears were then dried with forced-air at room temperature, repacked tightly into the original box and placed at 32°F overnight. Each box was vibrated the following day at 3.5-4 Hz with 1.1 G for 0.5 hours at 32°F and then stored at the same temperature. Skin browning induced by this method was examined 24 hours after treatment.

For effective treatments, treated pears were stored at 32°F for up to 9 days and 3 boxes were vibrated on day 1, 5 and 9 during storage, and the skin browning examined the following day. Skin browning was also induced by scuffing or hand-handling on an additional 30 pears (3 replication of 10 pears each) on the same days. For the scuffed pears, skin browning was evaluated 10 minutes after treatment. Hand-handling was inflicted on treated pears stored at 68°F (Table 1). In addition, a rolling method was also adopted to judge the effective treatments.

### **D. 1-MCP Treatment**

To further characterize the effect of 1-MCP (1-methylcyclopropene), an ethylene action inhibitor, in reducing skin browning, pears packed in commercial boxes were treated with 300 ppb 1-MCP in an air-tight tank for 12 hours at 32°F and then stored at 30°F. After 1, 2 or 3 months of storage at 30°F, pears were ripened at 68°F for 10 days. Fruit firmness and color changes were measured and handling-induced browning was inflicted every 2 days during the ripening period. Titratable acidity (TA) and soluble solid concentration (SSC) were analyzed at the beginning and the end of the shelf life period.

**Objective 2:** Develop a rapid test method to determine the susceptibility to skin browning of pear fruit, and further characterize the relationship between fruit firmness and susceptibility to skin browning.

The rapid methods for determination of total phenolics (nitroso test) and polyphenol oxidase (PPO) activity (catechol test) described by Kader and Chordas (1984) in peach flesh was further explored as a rapid test to determine the susceptibility to skin browning of pears. After measuring fruit firmness, the underside of peeled pear skin tissue was tested for total phenolics and PPO activity using the nitroso and catechol rapid test methods. The same fruit was scuffed by dragging the fruit 1 time for 20 inches over a coarse board. The incidence and intensity of skin browning caused by scuffing and the color intensity following the nitroso and catechol rapid tests was correlated. In addition, the results of the rapid tests were also compared with those of PPO activity and total phenolics content assayed biochemically. The developed rapid test was employed to determine susceptibility to skin browning of various pear samples and the sample pears were vibrated at 3.5-4 Hz with 1.1 G for 0.5 hour. The skin browning of the sample was examined 24 hours after treatment and the results were compared with the results of the rapid tests.

Our results from last year showed that pears harvested from different growing locations had different browning susceptibilities, and that susceptibility to browning was also related to fruit firmness. Fruit with higher firmness were less sensitive to browning, particularly within a growing location. Therefore, pear fruit obtained from various growing sources and harvest dates were vibrated by the previously described method and the relationship between firmness and vibration damage was further characterized.

### **A. Fruit Materials**

Commercially packed boxes of size 110 'Bartlett' pears were collected during the commercial harvest season from local packinghouses in Sacramento, Mendocino and Lake County of California. Pears were transported on the harvest day to the Pomology Postharvest Laboratory and cooled at 32°F overnight. The next day, 3 boxes of pears for each harvest were vibrated at 3.5-4 Hz with 1.1 G for 0.5 hour. An additional 40 pears from the same harvest were used to determine fruit firmness.

In addition, 20 pears from the same harvest were used for the rapid test method. Nitroso and catechol rapid tests as well as scuffing-induced skin browning were followed on each pear. The color intensity from the rapid test and scuffing were recorded subjectively on a 1-to-5 scale and also objectively with a Minolta Chroma Meter. Samples for biochemical analysis of PPO and total phenolics from each pear were frozen in liquid nitrogen and then stored at -112°F until analysis.

### **B. Flesh firmness and skin color**

Flesh firmness was determined with a GUSS automated fruit texture analyzer using a 5/16-inch probe [GUSS Manufacturing (Pty) Ltd., South Africa]. Skin was removed on two sides of the opposite equatorial region of each pear and firmness was measured on each side. External skin color on opposite sides of each fruit was measured with a Minolta Chroma Meter (Model CR-300, Minolta, Ramsey, N.J.) in CIE L\*a\*b\* mode. Changes in hue angle ( $h^\circ$ ), calculated as  $h^\circ = \arctan b^*/a^*$  (degree), were used to indicate the color change from green to yellow during ripening. Green  $\cong 116^\circ$ ; yellow  $\cong 98^\circ$ .

### **C. Nitroso and catechol rapid tests**

A procedure, originally developed by Kader and Chordas (1984) on peach, was tested for its ability to predict pear browning potential. This procedure involves two quick tests which show the intensity of PPO activity and the magnitude of the total phenolic content.

The catechol rapid test was used for PPO activity. The pear was peeled at the equatorial region to expose an inner area about 0.8 to 1.2 inch (2 to 3 cm) in diameter. One drop of 0.1 M catechol solution was applied to the area of the inner peel. Catechol is a phenolic compound and PPO enzyme in the tissue causes catechol to change to a brown compound. After 6 minutes, the

degree of brown discoloration was rated on a 1-to-5 scale. The higher the value, the higher the PPO activity.

The nitroso rapid test was used for total phenolics. A similar slice of pear tissue was used. One drop of each of the following reagents was applied in succession: sodium nitrite (10%), urea (20%) and acetic acid (10%). After 4 minutes, two drops of 8% sodium hydroxide solution was applied. The intensity of cherry-red color was evaluated on a 1-to-5 scale. Higher values indicate higher content of total phenolics.

#### **D. PPO assay**

The polyphenol oxidase (PPO) enzyme extraction and assay was a modification of the procedure of Barrett et al (1991). One gram of pear skin tissue was placed into 9.0 ml pH 7.0 extraction buffer which contained 50 mM phosphate buffer, 1 M KCl and 10% polyvinylpyrrolidone (PVPP). The sample was homogenized for 2 min at medium-high speed with a Polytron, filtered through four layers of cheesecloth and centrifuged at 10,000 g for 30 min at 4°C. The supernatant was decanted and filtered through Whatman #2 filter paper into an ice cold test tube and retained for PPO assay. All the above extraction procedures were at 4°C and the following assay procedure was carried out at 20°C. To assay the PPO activity, 0.25 ml supernatant extract and 2.75 ml pH 6.5 assay buffer containing 200 mM phosphate, 100 mM citrate and 100 mM catechol, were added to a 5 ml test tube and mixed. The increase in absorbance at 420 nm was recorded by spectrophotometry. PPO activity was expressed as an increase in absorbance at 420 nm per min per gram fresh weight.

#### **E. Total phenolics analysis**

The following extraction procedure was conducted at 4°C. One gram of pear skin tissue was placed into 9.0 ml 80% ethanol. The sample was homogenized for 2 min at medium-high speed with a Polytron, filtered through four layers of cheesecloth and centrifuged at 10,000 g for 30 min at 4°C. The supernatant was decanted and filtered through Whatman #2 filter paper into an ice cold test tube and retained for total phenolics determination. The following assay procedure was carried out at 20°C. To assay the total phenolics content, 0.5 ml supernatant extract and 5.0 ml reagent containing 0.027% Na / K-tartrate, 99 mM NaOH and 62.9 mM Na<sub>2</sub>CO<sub>3</sub>, were added to a 10 ml test tube and mixed. Ten to 15 min later, 1.0 ml of 1 N Folin-Ciocalteu's phenol reagent was added to the test tube and mixed. Absorbance at 660 nm was measured and recorded 30 to 60 min later. The total phenolics content in the pear skin was determined against a standard curve prepared by use of β-coumaric acid.

## 4. Results and Discussion

### 4.1 Confirm treatments with potential to reduce skin browning

Previous studies have shown that skin browning of pears can be reduced to some extent by

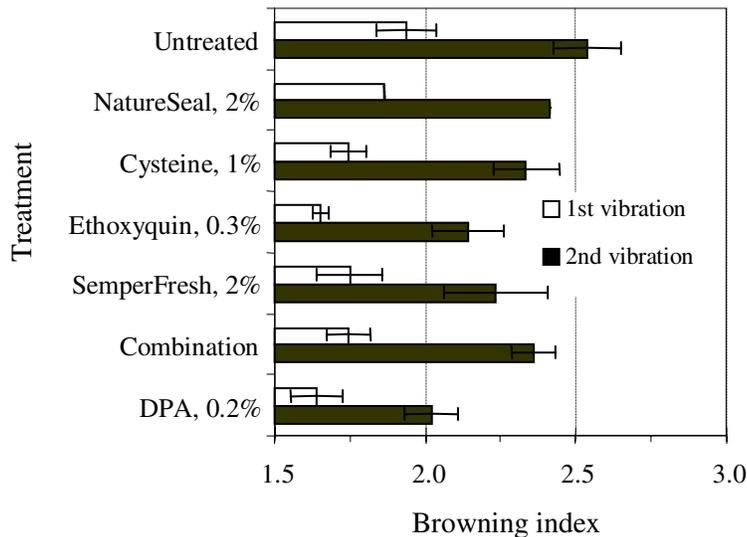


Figure 3. Effects of various compounds on skin browning of 'Bartlett' pears induced by vibration at 32°F. Second vibration occurred 3 days after the first one. Combination was a treatment with 2% ascorbic acid, 1% calcium lactate and 0.5% cysteine (pH 7).

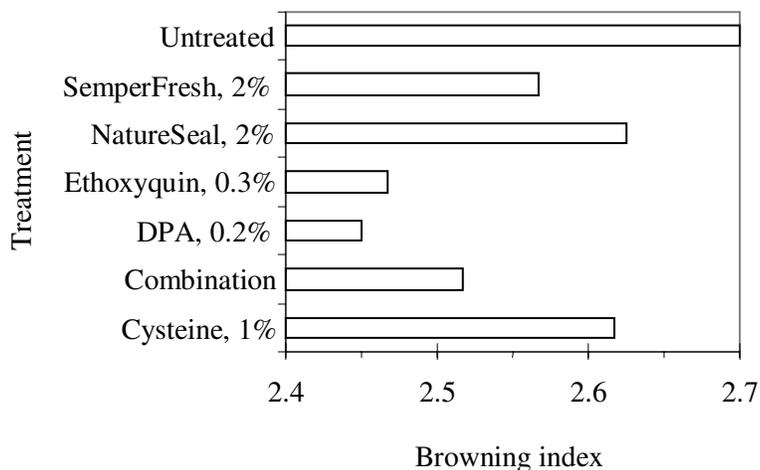


Figure 4. Effects of various compounds on skin browning of 'Bartlett' pears induced by rolling at 68°F. Combination was a treatment with 2% ascorbic acid, 1% calcium lactate and 0.5% cysteine (pH 7).

application of antioxidants or coatings. Last year, we explored several possible methods to control skin browning of pears, including application of coatings containing antioxidants or antioxidants alone. However, most of the compounds, showed no significant effect. Compounds that showed some effect to control skin browning of pears last year include a combination of 2% ascorbic acid, 1% calcium lactate and 0.5% cysteine (pH 7), DPA, Eth (ethoxyquin), cysteine and 1-MCP. The effect of these compounds were further evaluated this year.

As shown in Figure 3, all the tested compounds showed some effect in reducing skin browning of pears induced by vibration. DPA and Eth were the most effective compounds, they reduced skin browning by about 15%. When the same boxes of pears were vibrated for a second time after 3 days at 32°F, DPA reduced skin browning by 20% while Eth reduced skin browning by 16% compared with the untreated control. The compounds were also shown to be effective to some extent in reducing skin browning induced by rolling, the most effective compounds were also DPA and Eth (Figure 4). Compared with the control fruit, treatment with 0.2% DPA or 0.3%

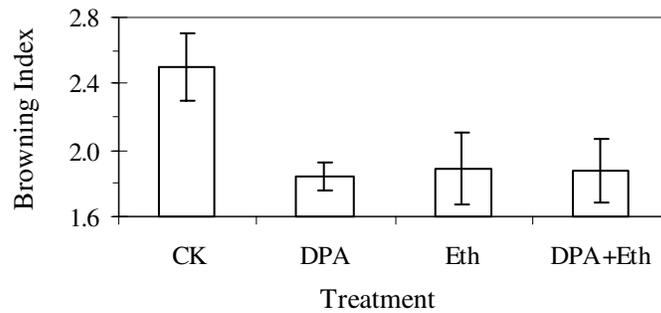


Figure 5. Confirmation of effects of diphenylamine (DPA) and ethoxyquin (Eth) on skin browning of ‘Bartlett’ pears induced by vibration at 32°F.

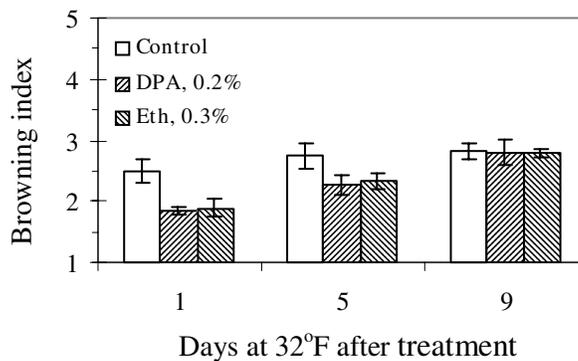


Figure 6. Effects of DPA and Eth on skin browning of ‘Bartlett’ pears induced by vibration at 32°F after various days of storage at 32°F after treatment.

Eth reduced the browning index by approximately 10%. To further confirm their effects, 0.2% DPA and 0.3% Eth were applied in a further experiment. Similar results were obtained, however, a combination of 0.2% DPA and 0.3% Eth did not enhance the control of skin browning induced by vibration (Figure 5). The reduced efficacy of cysteine and the combination treatment as compared with the 2001 results may be explained by poor control of vibration intensity during the 2001 testing.

To investigate how long the anti-browning effect of DPA and Eth is retained during storage at 32°F or 68°F, pears treated with 0.2% DPA or 0.3% Eth were stored at 32°F or 68°F after treatment, and browning was induced by vibration, scuffing or hand-handling after 1, 5 and 9 days of storage. When pears were vibrated in a tight-fill box, the effect of DPA and Eth lasted for 5 days during storage at 32°F (Figure 6). However, the reduction in browning was reduced from about 25% on day 1 after treatment to about 15% on day 5 after treatment. On day 9 after treatment, no effect was detected (Figure 6). Similar results were obtained when pears treated with DPA or Eth were inflicted with scuffing to induce skin browning (Figure 7). When DPA or Eth treated pears were stored at 32°F before being inflicted with hand-handling, the reduction in skin browning was about 23% and 14% after 1 and 5 days in storage, respectively. However, almost no effect was observed when pears were held at 68°F as little as 1 day after treatment before handling. This may be because at the higher temperature, the effect of DPA and Eth wore off more rapidly.

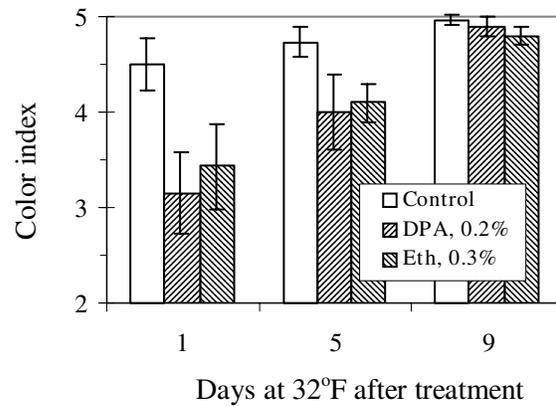


Figure 7. Effects of DPA and Eth on skin browning of 'Bartlett' pears induced by scuffing at 32°F after various days of storage at 32°F after treatment.

All the results show that treatment with 0.2% DPA or 0.3% Eth reduced skin browning on 'Bartlett' pears induced by vibration, rolling or scuffing. However, this effect was retained for only about 5 days when treated pears were stored at 32°F. This means that in practice, pears should be treated and packed immediately before transport to see any reduction in skin browning. DPA and Eth did not reduce skin browning on pears handled during ripening at 68°F

after treatment. Therefore, skin browning on ripening pears induced by handling can not be reduced by treatment with DPA or Eth before ripening the fruit at 68°F.

#### 4.2. Evaluation of 1-MCP to reduce skin browning on pears

1-MCP is an inhibitor of ethylene action and is effective in delaying ripening of pears. Last year, we found that treatment with 300 ppb 1-MCP reduced fruit browning potential, especially after one, two or three months of storage at 32°F. Although it was not very effective in inhibiting pear skin color change from green to yellow, it delayed fruit firmness loss during cold storage, and decreased the PPO activity and total phenolics content. The data suggest that 1-MCP is a possible candidate for control of skin browning and at the same time for control of fruit ripening to satisfy market needs. This year, 1-MCP treatment was repeated and the effect of 1-MCP on skin browning of ‘Bartlett’ pears during shelf life was evaluated. The effect of 1-MCP on firmness, color change, respiratory rate and ethylene evolution, as well as TA and SSC were also investigated.

The results show that treatment with 300 ppb 1-MCP delayed fruit ripening of ‘Bartlett’ pears (Figures 8 and 9 and Table 2). As shown in Figure 8, softening of pears treated with 1-MCP was delayed during shelf life at 68°F. However, the effect of 1-MCP to delay fruit softening was decreased after pears were stored at 30°F for a longer time. Fruit firmness decreased slightly during storage at 30°F, and the magnitude of this decrease was reduced by treatment with 1-MCP (Figure 8 and Table 2). The color change from green to yellow was similarly delayed both during storage at 30°F (Table 2) and shelf life at 68°F (Figure 8). When transferred from storage at 30°F to shelf life at 68°F, the appearance of the ethylene evolution peak (Figure 10) and the respiration peak (Figure 9) was delayed. There was less of a delay the longer fruit were stored at 30°F (Table 2). The results suggest that cold storage alone is not enough to protect pears from

Table 2. Effect of 1-MCP on ripening delay of ‘Bartlett’ pears during storage at 30°F and shelf life at 68°F compared with control pears

Time stored at 30°F (months)		1	2	3
During storage at 30°F	Reduction of fruit softening (%)	7.5	8.1	8.2
	Reduction of color change (decrease in H value)	1.694	3.810	5.354
During shelf life at 68°F	Delay of time to get firmness of ~5 lb (days)	~4	~3	~2
	Delay of sensitivity to skin browning induced by handling (days)	4	~3	2
	Delay of ethylene evolution peak (days)	4	3	2
	Delay of respiratory peak (days)	~4	~3	~2

ripening during long-term storage even when the temperature is as low as 30°F. Other measures have to be considered to achieve successful long-term cold storage. 1-MCP treatment may be a good measure for this purpose.

The results from 2001 showed that 1-MCP treatment decreased the sensitivity of ‘Bartlett’ pears to skin browning induced by vibration when the vibration was inflicted after storage at 32°F for 1, 2 or 3 months. The 2002 results agree and also show that 1-MCP treatment decreased the sensitivity of pears to skin browning induced by hand-handling during shelf life at 68°F after

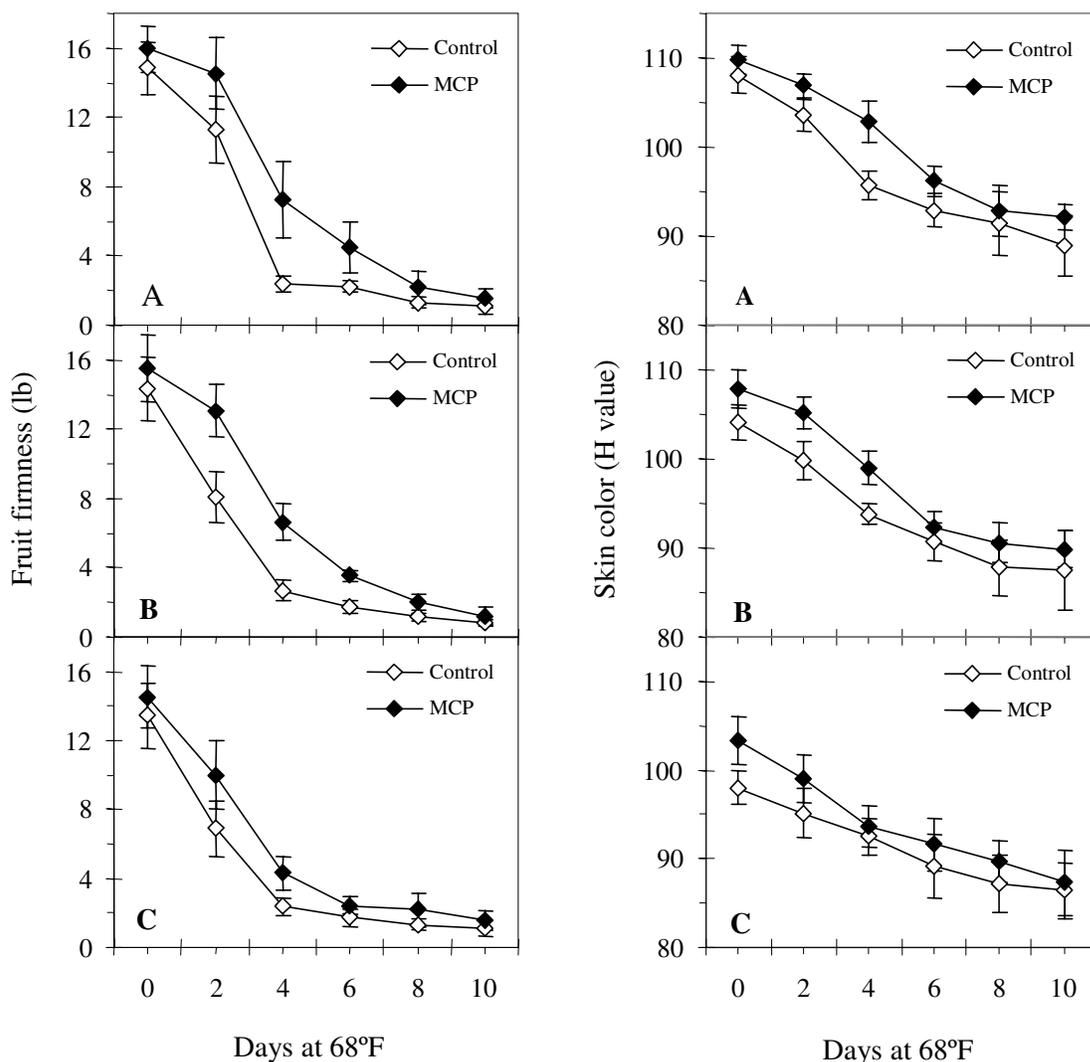


Figure 8. Effect of 1-MCP on firmness (left column) and color change (right column) of ‘Bartlett’ pears during shelf life at 68°F after storage at 30°F for 1 (A), 2 (B) or 3 (C) months. Pears were treated with 300 ppb 1-MCP on the harvest day for 12 hour at 32°F and then transferred to 30°F for indicated period.

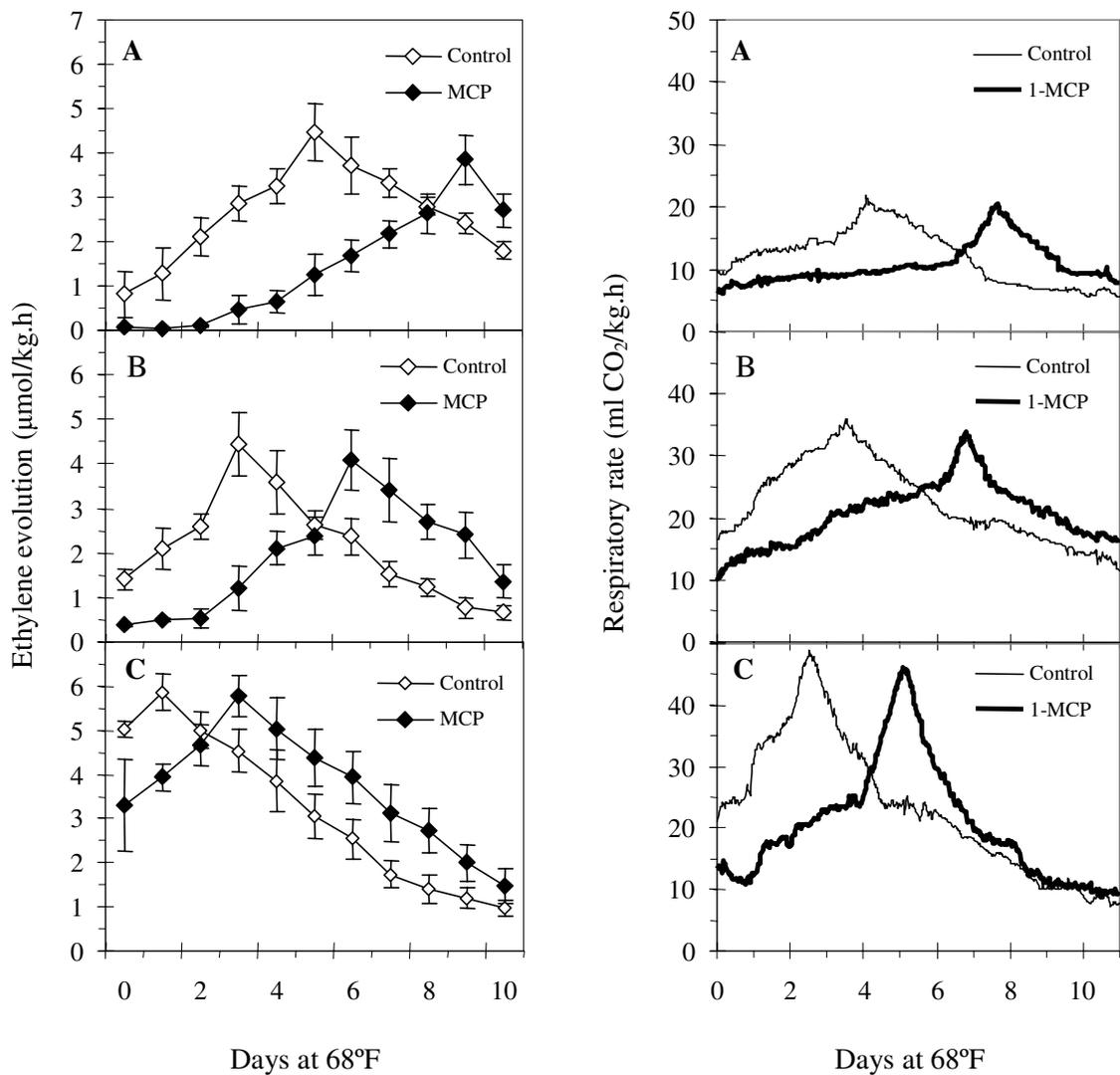


Figure 9. Effect of 1-MCP on ethylene evolution (left column) and respiratory rate (right column) of 'Bartlett' pears during shelf life at 68°F after storage at 30°F for 1 (A), 2 (B) or 3 (C) months. Pears were treated with 300 ppb 1-MCP on the harvest day for 12 hour at 32°F and then transferred to 30°F for indicated period.

storage at 30°F for various periods (Figure 10). This effect decreased as pears were stored for a longer time at 30°F (Table 2). Our other results showed that fruit sensitivity to skin browning was related to their firmness. We found that when fruit firmness decreased to about 2 lb, no difference in skin browning induced by hand-handling was observed between pears treated with or without 1-MCP. In addition, skin browning induced by hand-handling was not immediately visible when fruit firmness was greater than ~5 lb. These results account for the lack of difference in sensitivity to skin browning induced by hand-handling between control and 1-MCP treated pears at the beginning and the end of shelf life at 68°F (Figure 10). The effect of 1-MCP

on TA and SSC in pears was not significant, likely because TA and SSC did not change during fruit ripening.

The results that 1-MCP decreased sensitivity of ‘Bartlett’ pears to skin browning induced by both vibration and hand-handling is significant for the pear industry. Once 1-MCP is registered for use on pears in California, it should be considered as a possible method for control of skin browning. There are several advantages to use 1-MCP for this purpose. First, it is a one-time application and the effects last for a long time. Treatment can be carried out either before or after pears are packed. Secondly, it showed multi-functions for one treatment. Both skin browning induced by vibration during transport and induced by hand-handling during marketing can be reduced. Thirdly, there exists a possibility to control the magnitude of skin browning by adjusting the concentration of 1-MCP applied. It has been well established that 1-MCP delays pear fruit ripening for a longer time if a higher concentration of 1-MCP is applied. As 1-MCP reduced the sensitivity of ‘Bartlett’ pears to skin browning by delaying fruit ripening, it may be

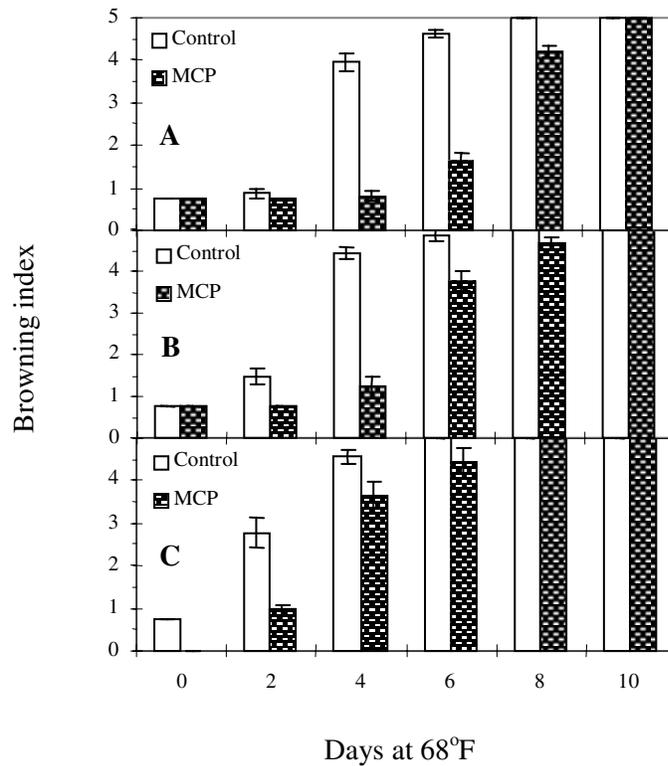


Figure 10. Effect of 1-MCP on skin browning of ‘Bartlett’ pears induced by hand-handling during shelf life at 68°F after storage at 30°F for 1 (A), 2 (B) or 3 (C) months. Pears were treated with 300 ppb 1-MCP on the harvest day for 12 hour at 32°F and then transferred to 30°F for indicated period.

possible to maintain the effect of 1-MCP on reducing sensitivity to skin browning a longer time by using a higher concentration of 1-MCP. However, this needs to be considered together with the required time for pears to ripen.

### 4.3. Characterize the relationship between fruit firmness and skin browning

Results from 2001 showed that there was a consistent relationship between firmness and browning potential for fruit vibrated and harvested from various locations and harvest dates during ripening. All the results indicate that pears with higher firmness showed lower browning potential. Therefore, fruit firmness can be suggested as an indicator to predict its sensitivity to browning caused by mechanical injury. This year we further investigated the relationship between fruit firmness and browning potential and tried to develop a standard for using fruit firmness as an indicator of the browning potential of pears.

Fruit firmness on the harvest date was measured before vibration (Table 3). The relationship between browning index and fruit firmness is shown in Figure 11. Similar results were obtained last year. Pears with higher fruit firmness were less sensitive to skin browning. However, as was found last year, pears harvested from different growing locations developed different amounts of browning following the vibration treatment. Fruit from Mendocino were found to be the most sensitive pears, in agreement with our results in 2001.

Table 3. Fruit firmness of 'Bartlett' pears from various locations and harvest dates

Location	Harvest		Firmness* (lbs)
	No.	Date	
Sacramento	1	July, 19	17.62 ± 1.22
	2	July, 24	17.63 ± 1.40
	3	July, 24	17.64 ± 1.38
	4	Aug, 7	14.45 ± 1.26
Mendocino	1	July, 31	15.85 ± 1.93
	2	Aug, 6	16.09 ± 1.18
	3	Aug, 13	16.55 ± 1.87
	4	Aug, 20	15.62 ± 1.28
Lake County	1	Aug, 6	17.77 ± 1.51
	2	Aug, 13	18.32 ± 1.91
	3	Aug, 26	14.68 ± 1.89

\* Mean of 40 pears ± standard deviation.

The two years' results suggest that fruit firmness is an indicator of the browning potential of 'Bartlett' pears. The following standard is suggested for possible use in practice: Select 40 pears randomly from a lot and determine their average firmness, then predict the browning index of the lot and judge their browning potential according to Table 4. This method was employed in our

experiments to predict browning potential of pears harvested from various locations and the results were relatively consistent (Figure 11). It should be emphasized that the results were obtained with size 110 pears and they may not be suitable for other sized pears (see Figure 12).

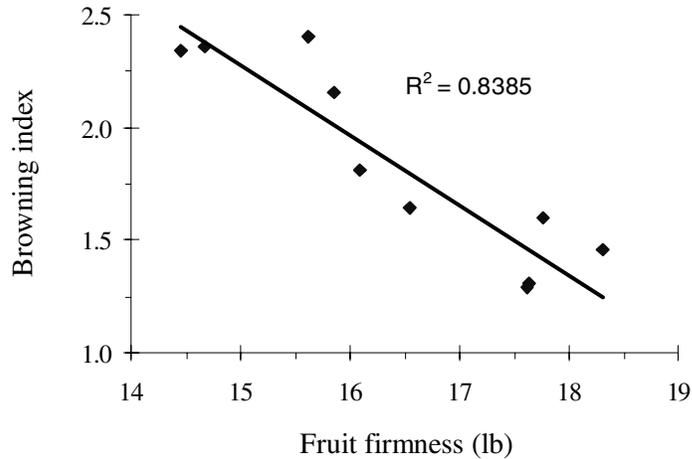


Figure 11. Relationship of firmness of ‘Bartlett’ pears harvested from various locations and their sensitivity to skin browning induced by vibration at 3.5 Hz with 1.1 G for 0.5 hour.

Table 4. Suggested standard for prediction of browning potential of ‘Bartlett’ pear based on their fruit firmness

Fruit firmness (lb)	Predicted browning index *	Browning potential
> 17	< 1.3	Low sensitivity
16 to 17	1.3 – 1.8	Sensitive
15 to 16	1.8 – 2.3	High sensitivity
< 15	> 2.3	Very sensitive

\* When browning index is 0.75, there is no browning.  
Index developed with size 110 pears.

#### 4.4. Evaluate browning potential of pears with different sizes

In 2001, we determined that skin browning of ‘Bartlett’ pears was dependent on the severity of mechanical injury and fruit PPO activity and phenolics content. The magnitude of the PPO activity and total phenolics content influence the amount of browning that develops when mechanical injury occurs. However, no matter how high the PPO activity and total phenolics were, only mechanical injury triggered the browning process. Therefore, a key measure to avoid skin browning is to prevent the mechanical injury. As mechanical injury results from friction

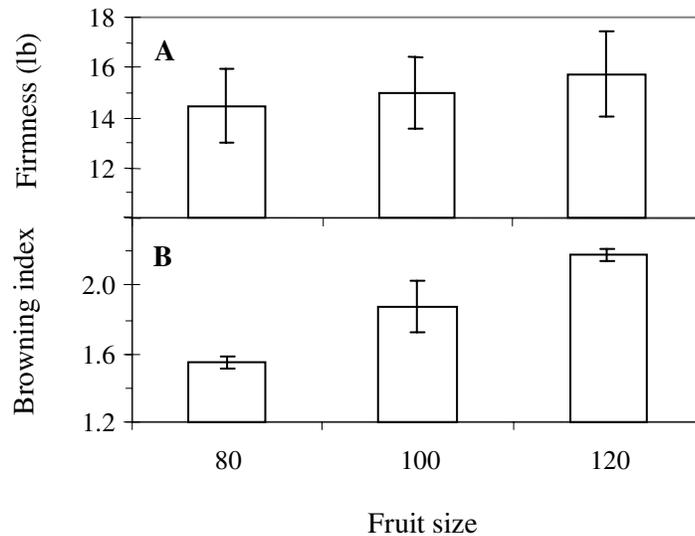


Figure 12. Firmness (A) and sensitivity (B) of different sizes of ‘Bartlett’ pears to skin browning induced by vibration at 3.5 Hz with 1.1 G for 0.5 hour.

between pears, immobilizing the fruit within the box during transportation is key to reducing browning. In some tests with very large pears, skin browning was unexpectedly low. Therefore, the browning potential of pears of different sizes was investigated. As shown in Figure 12A, the browning index increased significantly as fruit size decreased from 80 to 120. However, no significant differences in fruit firmness were found between the pears of different sizes (Figure 12B). Therefore, the difference in browning index was considered mainly from the difference in the size of the pears. The difference could be due to how well the different sized fruit were immobilized in the box or to differences in PPO activity and total phenolics content between the different sized pears. This requires further investigation.

#### 4.5. Explore a rapid test to determine sensitivity of pears to browning

Skin browning is a major cause of customer dissatisfaction for ‘Bartlett’ pears. It would be beneficial for the industry to have a rapid method to determine the sensitivity to browning of a given lot of fruit. Last year we began to explore a rapid test. This rapid test was further characterized in 2002 and a standard protocol was developed.

Ten pears selected randomly from each fruit lot harvested from different locations were used for this part of the experiment. After measuring firmness, pears were tested by application of the rapid test methods. The method includes two parts. One is the nitroso test for rapid determination of total phenolics content and the other is the catechol test for quick determination of PPO activity. The same fruit were then inflicted with scuffing injury. The rate and intensity of

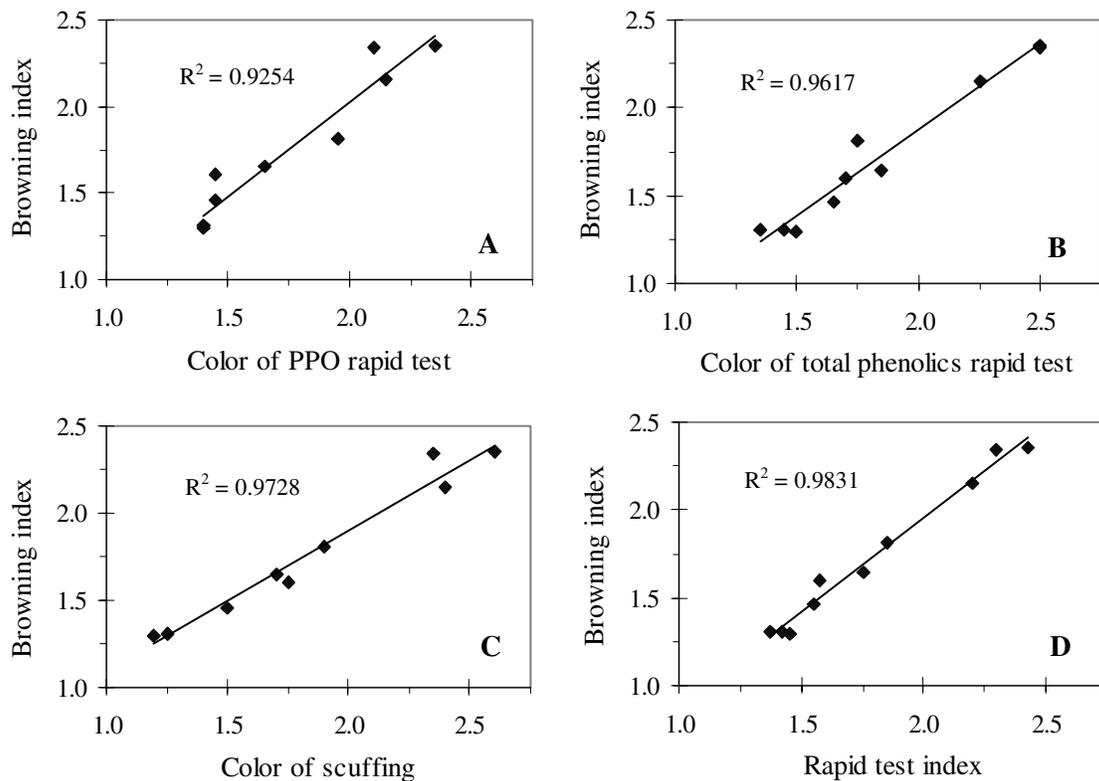


Figure 13. Relationship of PPO rapid test color (A), total phenolics rapid test color (B), scuffing-induced browning (C) and rapid test index (D) to the vibration-induced browning index.

browning caused by scuffing and the color change with the rapid tests were related to the vibration-induced browning index of the fruit lot from which the 10 fruit were selected. Skin samples were also taken from the same fruit for biochemical analysis of PPO activity and total phenolics content.

The results show that PPO activity determined by the catechol rapid test (Figure 13A) and total phenolics content determined by the nitroso rapid test (Figure 13B) as well as scuff browning color (Figure 13C) were positively related to the browning index of the original fruit lot resulting from vibration at 3.5 Hz with 1.1 G for 0.5 hour. To consider the color of the rapid tests for both PPO and total phenolics, another index called the rapid test index, which was the arithmetic mean of all the color values of the PPO and total phenolics rapid tests, was also used. This rapid test index was also positively related to the browning index of the fruit lot (Figure 13D) and the  $R^2$  value was higher than for either rapid test alone. The results of the biochemical analysis of PPO activity and total phenolics on skin samples taken from the same fruit used for the rapid tests, show that both the PPO and total phenolics rapid tests were consistent with the results of the biochemical analysis (Figure 14 and 15). All the correlations between the rapid test results and skin browning were better than the correlation between firmness and skin browning

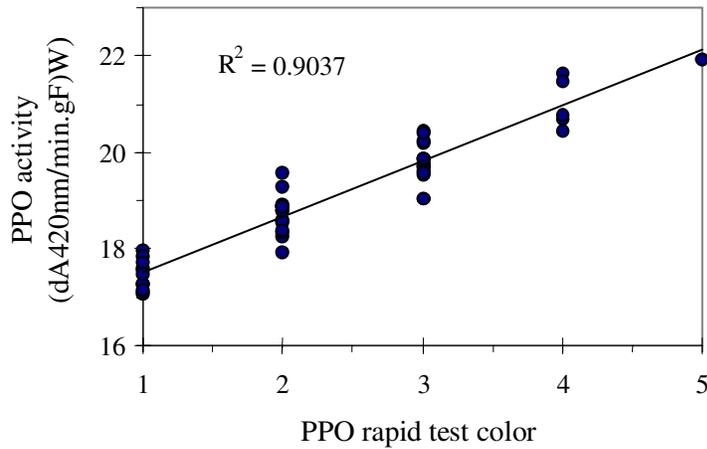


Figure 14. Relationship between PPO rapid test color and biochemical analysis of PPO activity

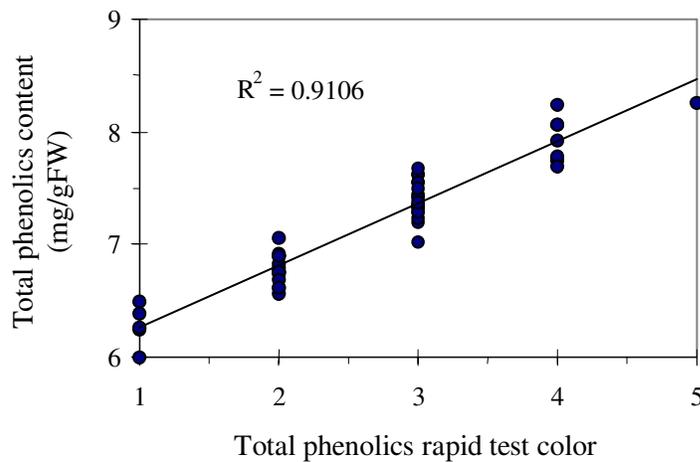


Figure 15. Relationship between total phenolics rapid test color and biochemical analysis of total phenolics content

These results suggest that the color changes obtained from the rapid tests can be good indicators to predict the browning potential of pears. The following protocol is suggested for the rapid test: Select 10 pears randomly from a fruit lot, carry out PPO and / or total phenolics rapid test(s), subjectively score the color of each sample on a 1-to-5 scale, calculate the average color value of PPO color or total phenolics color, or the rapid test index if both PPO and total phenolics rapid tests were done. Then, predict the sensitivity of the fruit lot according to Table 5.

Table 5. Suggested standard for prediction of browning potential of ‘Bartlett’ pear based on color value from rapid tests

Average color value	Predicted browning index	Browning potential
< 1.4	< 1.3	Low sensitivity
1.4 to 1.8	1.3 – 1.8	Sensitive
1.8 to 2.5	1.8 – 2.3	High sensitivity
> 2.5	> 2.3	Very sensitive

## 5. Conclusion

Skin browning susceptibility is closely related to pear firmness, particularly within a growing area. Fruit from Mendocino consistently had higher levels of skin browning at a given firmness level. Smaller fruit were more susceptible to skin browning than large fruit, irrespective of firmness. Treatment of pears with 1-MCP reduced the susceptibility to skin browning immediately after storage and during ripening, mostly due to inhibition of fruit softening. The rapid tests developed were excellent predictors of skin browning; however, the ease of firmness measurement as compared with the rapid test may make firmness a preferred method to predict skin browning.

## 6. Future research

Investigate the effect of different concentrations of 1-MCP on the sensitivity of pears to skin browning, evaluate if different concentrations of 1-MCP can be used to control ‘Bartlett’ pear skin browning for different periods of storage while assuring that fruit ripen adequately for marketing. Determine the causes of variability in sensitivity to skin browning between pears of different sizes

## References:

- Amarante, C., N.H. Banks and S. Ganesh. 2001. Effect of coating concentration, ripening stage, water status and fruit temperature on pear susceptibility to friction discoloration. *Postharv. Biol. Technol.* 21: 283-290
- Barrett, D.M., C.Y. Lee and F.W. Liu. 1991. Changes in the activity and subcellular distribution of PPO in ‘Delicious’ apples during controlled atmosphere storage. *J. of Food Biochemistry*, 15: 185-199
- Kader, A.A. and A. Chordas. 1984. Evaluation the browning potential of peaches. *California Agriculture*. 38 (344): 14-15

- Mellenthin, W.M. and C.Y. Wang. 1974. Friction discoloration of 'd' Anjou' pears in relation to fruit size, maturity, storage and polyphenoloxidase activities. *HortScience*, 9: 592-593
- Scott, L.E., G.E. Mattus and L.L. Claypool. 1959. Observations on the browning reaction in bruised Bartlett pears. *Amer. Soc. Hort. Sci.*, 75: 106-113
- Slaughter, D.C., R.T. Hinsch and J.F. Thompson. 1993. Assessment of vibration injury to Bartlett pears. *American Society of Agricultural Engineers*. 36 (4): 1043-1047
- Tomas-Barberan, F.A. and J.C. Espin. 2001. Phenolic compounds and related enzymes as determinants of quality in fruits and vegetables. *J Sci Food Agric*. 81: 853-876
- Vamos-Vigyazo and V. Nadudvari-Markus. 1982. Enzymatic browning, polyphenol content, polyphenol oxidase and peroxidase activities in pear cultivars. *Acta Alimentaria*, 11: 157-168
- Wang, C.Y. and W.M. Mellenthin. 1974. Inhibition of discoloration on 'd' Anjou pears by 2-mercaptobenzothiazole. *HortScience*, 9:196