

Winter Pear ('Anjou' and 'Bosc') Response to Methyl Bromide Fumigation

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Abstract. MeBr fumigation of 'Anjou' pears reduced external skin color values and increased the incidence of scald whether applied immediately after harvest or after 5 months of controlled-atmosphere (CA) storage. MeBr treatment did not influence external color of 'Bosc' pears (*Pyrus communis* L.). Internal discoloration of 'Bosc' pears was apparent only in fruit from CA storage and those that were not in good physiological condition before fumigation. Internal discoloration was apparent by either objective or subjective procedures. Firmness values of 'Bosc' pears increased with MeBr fumigation and treated pears softened as readily as nonfumigated pears. Reaction of these winter pears to MeBr fumigation was not dose-dependent. Chemical name used: methylbromide (MeBr).

Export of agricultural commodities to foreign markets is a major interest of the United States. Quarantine barriers established to prevent spread of agricultural pests are a limiting factor. Fumigation with methyl bromide (MeBr) to control insect pests, such as codling moth [*Cydia pomonella* L. (Lepi-

doptera:Tortricidae)] has often met with varying degrees of success due to injury of the host fruit. This host-fruit injury is directly related to the high dosage of MeBr required to eliminate the insect in question and meet quarantine requirements.

Insect control in both dark- and light-colored cultivars of sweet cherries (*Prunus avium* L.) was obtained with MeBr and little or no injury or quality degradation was evident (Anthon et al., 1975; Drake et al., 1991; Moffitt et al., 1977). Apples (*Malus domestica* Borkh.) have also been treated with MeBr to control insects; however, injury and quality degradation have been noted with some cultivars (Chapman, 1940; Claypool and Vines, 1956; Drake et al., 1988; Kenworthy, 1944; Kenworthy and Gaddis, 1946; Meheriuk et al., 1990; Phillips and Monro, 1939; Phillips et al., 1938).

No information is available on the response of winter pears to MeBr and, consid-

ering the expanding production of titer pears and the increased interest in exportation, this study was initiated to determine the response of winter pears ('Anjou' and 'Bosc') to MeBr fumigation.

Three groups of packed size 100 (220 g) U.S. No. 1 'Bosc' and 'Anjou' pears were obtained from Yakima, Wash., area packinghouses either shortly after harvest or after 5 months of controlled-atmosphere (CA) storage (2% to 3% O₂, 1% CO₂ for both cultivars). Pears were treated with thiabendazole to control decay and coated with food-grade shellac-based wax. All pears were then stored at 1.1C until tests were initiated. All pears (control and fumigated) were conditioned for 12 to 18 h at 6C before fumigation.

The first group of pears was obtained 30 Jan. ('Bosc') and 21 Feb. ('Anjou') 1990, after 5 to 6 months of CA storage. The first group of 'Bosc' pears was treated on 2, 9, or 15 Feb., and the first group of 'Anjou' pears were treated 23 Feb. and 2 or 8 Mar. 1990. The second group of pears was obtained 17 Sept. [replication no. 1 ('Bosc')] and 1 Oct. 1990 [replication no. 2 and 3 ('Bosc')] and all replications ('Anjou') on 1 Oct. 1990. This group of 'Bosc' pears was treated on 25 or 27 Sept. or 2 Oct. and the 'Anjou' pears were treated 4, 11, or 16 Oct. 1990. The third group of 'Bosc' and 'Anjou' pears was obtained 11 Feb. 1991 after 5 to 6 months of CA cold storage. This group of 'Bosc' pears was treated 12, 14, or 19 Feb., and the 'Anjou' pears were treated on 21, 26, or 28 Feb. 1991.

For each cultivar, nine replications of 36 pears each were fumigated with MeBr at 0, 32, 40, or 48 g·m⁻³ for 2 h with fruit at 6C, thus, there were three replications per treatment on each fumigation date. Three replications of untreated fruit were included for each cultivar on each treatment date. Treatment regimes selected were within the range of those under study by us for control of the codling moth and other arthropod pests to meet quarantine requirements for several deciduous fruits.

Received for publication 19 Aug. 1991. Accepted for publication 24 Feb. 1992. Product names are necessary to report factually on available data; however, the U.S. Dept. of Agriculture (USDA) neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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Table 1. Winter pear ('Anjou' and 'Bosc') quality during cold storage, fumigated with methyl bromide <2 weeks after harvest 1990.

Variable	Hunter color						Firmness (N)	Scald (%)	Visual score ^z
	External			Internal					
	"L"	"b"	Hue	"L"	"b"	Hue			
<i>Anjou</i>									
MeBr (g·m ⁻³)									
0	71.9 a ^y	31.3 NS	91.2 NS	72.1 a	17.7 NS	84.9 NS	26.7 NS	0.3 c	1.0 b
32	70.5 b	31.1	90.6	71.4 b	17.8	85.1	25.3	30.8 a	1.9 a
40	69.7 c	30.9	90.8	71.4 b	18.0	85.4	27.2	30.0 a	1.8 a
48	70.8 b	31.1	91.2	71.5 b	18.1	85.0	27.2	14.2 b	1.3 b
Days in storage (after fumigation)									
30	68.7 b	30.2 b	93.7 a	73.4 a	17.4 b	84.8 NS	31.1 a	0.0 b	1.0 b
60	73.6 a	32.2 a	88.5 b	71.1 b	18.3 a	85.2	22.1 b	25.3 a	1.7 a
Ripening (days)									
0	68.2 b	30.0 b	95.0 a	71.9 NS	18.0 NS	84.9 NS	40.9 a	11.4 b	1.3 NS
8	74.1 a	32.4 a	87.1 b	71.6	17.6	85.2	12.4 b	13.9 a	1.3
<i>Bosc</i>									
MeBr (g·m ⁻³)								Pithy brown core (%)	Visual score ^z
0	57.4 NS	26.7 NS	63.2 NS	66.5 NS	18.9 NS	83.1 NS	30.3 c	15.0 NS	1.2 NS
32	57.5	26.6	63.8	68.5	19.1	83.1	33.5 b	17.5	1.2
40	57.6	26.6	63.5	69.1	19.1	83.3	34.1 ab	10.8	1.2
48	57.1	26.0	64.0	68.1	18.8	84.0	37.1 a	17.5	1.2
Days in storage (after fumigation)									
30	57.4 NS	26.0 b	65.7 a	68.9 NS	18.7 b	83.5 a	33.9 a	1.1 b	1.0 b
60	57.3	27.1 a	61.3 b	66.3	19.2 a	82.8 b	31.3 b	29.2 a	1.4 a
Ripening (days)									
0	57.1 NS	25.9 b	66.2 a	68.7 NS	19.7 a	83.2 NS	45.4 a	2.8 b	1.0 b
8	57.6	27.3 a	60.9 b	66.5	18.3 b	83.0	20.6 b	27.5 a	1.4 a

^aVisual rating on a scale of 1 to 5 (1 = 0% scald; 5 = 100% scald).

^yMean separation within treatments by Duncan's multiple range test ($P = 0.05$).

^zVisual rating on a scale of 1 to 5 (1 = 0% internal discoloration; 5 = 100% internal discoloration).

Table 2. 'Anjou' pear quality during cold storage, fumigated with methyl bromide after 5 to 6 months controlled-atmosphere storage.

Variable	Hunter color						Firmness (N)	Scald (%)	Visual score ^z
	External			Internal					
	"L"	"b"	Hue	"L"	"b"	Hue			
<i>Spring 1990</i>									
MeBr (g·m ⁻³)									
0	63.3 a ^y	28.2 a	83.7 NS	75.3 NS	19.3 NS	85.0 NS	34.0 NS	35.8 b	2.1 b
32	61.1 b	27.4 b	84.4	75.7	19.3	85.9	34.9	50.3 a	2.8 a
40	61.3 b	27.5 b	84.4	74.5	19.4	85.9	34.8	47.4 a	2.5 ab
48	61.9 b	27.8 b	84.4	75.5	19.4	85.9	34.2	45.5 a	2.5 ab
Days in storage (after fumigation)									
0	62.2 NS	28.1 NS	83.1 c	75.3 NS	19.1 b	86.0 a	36.0 a	33.0 c	1.8 c
30	62.3	28.0	84.1 b	75.6	19.3 a	85.8 b	33.8 b	40.5 b	2.5 b
60	62.5	27.7	85.0 a	75.2	19.5 a	85.7 b	33.2 b	51.8 a	2.8 a
Ripening (days)									
0	61.7 b	26.9 b	79.0 a	76.0 a	19.8 a	86.1 a	55.2 a	6.4 b	1.2 b
8	63.0 a	28.9 a	88.5 a	74.8 b	18.8 b	85.7 b	13.3 b	77.1 a	3.5 a
<i>Spring 1991</i>									
MeBr (g·m ⁻³)									
0	65.2 a	29.3 a	94.7 NS	72.8 NS	39.9 NS	86.7 NS	36.8 NS	37.1 b	1.5 b
32	62.8 c	28.1 b	89.8	71.9	40.3	86.9	37.0	63.3 a	2.0 a
40	63.9 b	28.6 b	94.1	72.0	40.1	86.9	37.9	57.2 a	1.8 a
48	64.0 b	28.6 b	94.1	71.9	40.0	86.9	37.1	53.3 a	1.8 a
Days in storage (after fumigation)									
0	63.4 b	28.7 NS	96.4 a	72.4 a	39.9 NS	87.2 a	40.0 a	43.3 b	1.6 b
30	64.6 a	28.6	91.7 b	71.5 b	40.3	86.9 b	36.9 b	39.6 b	1.5 b
60	63.9 ab	28.7	91.4 b	71.9 ab	40.7	86.4 c	34.7 c	75.3 a	2.1 a
Ripening (days)									
0	62.1 b	27.2 b	98.7 a	72.3 a	40.8 a	87.3 a	54.8 a	54.8 a	1.4 b
8	65.9 a	30.2 a	87.6 b	71.5 b	39.4 b	86.4 b	19.6 b	19.6 b	2.1 a

^aVisual rating on a scale of 1 to 5 (1 = 0% scald; 5 = 100% scald).

^yMean separation within treatments by Duncan's multiple range test ($P = 0.05$).

Table 3. 'Bosc' pear quality during cold storage, fumigated with methyl bromide after 5 months controlled-atmosphere storage.

Variable	Hunter color						Firmness (N)	Pithy brown core (%)	Visual score ^z
	External			Internal					
	"L"	"b"	Hue	"L"	"b"	Hue			
<i>Spring 1990</i>									
MeBr (g·m ⁻³)									
0	52.7 NS	25.1 NS	64.9 NS	71.4 a ^y	19.4 a	84.7 a	36.2 NS	22.7 b	1.3 b
32	52.0	24.3	65.2	66.7 b	18.7 b	80.9 b	34.2	49.9 a	2.0 a
40	51.8	24.3	64.8	67.1 b	18.9 b	80.7 b	35.0	52.7 a	2.1 a
48	52.1	24.3	65.4	67.3 b	18.9 b	80.7 b	34.8	40.9 a	2.0 a
Days in storage (after fumigation)									
0	51.6 b	24.8 NS	67.9 a	70.2 NS	19.0 b	83.5 a	36.4 NS	26.5 b	1.6 NS
30	52.9 a	24.4	64.7 b	69.4	19.4 a	82.4 b	34.8	35.5 a	1.7
60	52.6 ab	24.9	62.5 b	69.5	19.1 ab	82.3 b	35.3	43.9 a	1.8
Ripening (days)									
0	51.4 b	23.9 b	68.5 NS	72.0 a	19.7 a	84.1 a	52.4 a	19.4 b	1.2 b
8	53.4 a	25.4 a	61.6	67.4 b	18.6 b	81.4 b	18.6 b	51.2 a	2.3 a
<i>Spring 1991</i>									
MeBr (g·m ⁻³)									
0	46.6 NS	21.4 NS	57.7 NS	68.3 NS	20.5 NS	85.4 b	40.8 b	0.0 NS	1.0 NS
32	46.5	20.9	58.1	68.6	20.6	86.0 a	41.5 ab	0.0	1.0
40	46.8	20.9	58.3	68.8	20.8	85.8 ab	41.4 ab	0.0	1.0
48	46.5	20.7	58.4	68.7	20.6	86. a	42.3 a	0.0	1.0
Days in storage (after fumigation)									
0	45.4 b	20.2 b	61.2 a	68.7 a	20.2 b	86.9 a	43.1 a	0.0	1.0
30	47.2 a	21.2 a	58.6 b	69.3 a	20.9 a	85.4 b	41.2 b	0.0	1.0
60	47.3 a	21.6 a	54.6 c	67.8 b	20.8 a	85.1 b	40.3 c	0.0	1.0
Ripening (days)									
0	44.5 b	19.6 b	62.2 a	68.7 NS	20.5 b	87.1 NS	53.3 a	0.0	1.0
8	48.7 a	22.3 a	54.0 b	68.4	20.8 a	84.5	29.7 b	0.0	1.0

^zVisual rating on a scale of 1 to 5 (1 = 0% internal discoloration; 5 = 100% internal discoloration).

^yMean separation within treatments by Duncan's multiple range test ($P = 0.05$).

All fumigations were conducted in 28.3-liter fiberglass chambers (Model 55300; Labconco Vacuum Desiccators, Kansas City, Mo.) equipped with circulating fans operated throughout the exposure period. The chambers were located in a walk-in controlled-environment room, and the temperature in the chambers depended on the temperature of the room. Test pears in each chamber were kept in a perforated metal basket designed to allow flow of the fumigant and to have a 50% load factor (v/v) when filled. Each chamber contained pears from a single replication. All fumigations were conducted with a 2-h exposure and aeration periods at normal atmospheric pressure.

Fruit pulp temperatures were monitored using a Campbell 21X digital recorder (Campbell Scientific, Logan, Utah) equipped with copper-constantan thermocouples. For each chamber, a thermocouple was inserted into the pulp of one pear in the center of the load. Temperatures were recorded after 0, 10, 30, 60, and 120 min of exposure. While the planned fruit temperature at initiation of fumigation was 6C, observed fruit temperatures ranged from 3.6 to 6.7C.

After fumigation, pears were stored at 1C for 30 or 60 days before evaluation. Storage evaluations consisted of 20 pears for all combinations of MeBr treatment and replications. Ten pears were evaluated immediately after removal from storage and the other 10 were allowed to ripen for 8 days at ambient temperature (20C) before evaluation for acceptability. Quality factors evaluated were

external and internal color, firmness, soluble solids content (SSC), titratable acidity, and visual disorders. Production of CO₂ and G₃H₄ was determined using the procedure described by Drake et al. (1988). External and internal color were determined with The Color Machine (Pacific Scientific, Silver Spring, Md.) using the Hunter "L," "a," "b" scale calibrated with a White CM536 plate. Three values for external color were determined around the circumference of the fruit, and the average value for 10 fruit is reported. Internal color was measured by cutting each fruit in half equatorially and immediately reading the exposed flesh surface of the calyx end in a sample cup. A Model EP1 pressure tester (Lake City, Kelowna, B.C., Canada) equipped with a 1.27-cm head was used to determine firmness. Juice was titrated to pH 8.2 with 0.1 N NaOH and titratable acidity expressed as percentage of malic acid. Visual ratings of disorders (external and internal) were on a scale of 1 to 3 (1 = acceptable, 2 = fair, 3 = unacceptable).

'Anjou' pears fumigated with MeBr displayed external disorders directly related to MeBr fumigation shortly after harvest. MeBr-treated 'Anjou' pears had lower external Hunter "L" color values (≈2%) when compared to control fruit, but the "b" and hue values were not affected (Table 1). This difference in brightness ("L" value) between fumigated and unfumigated was visible. MeBr also increased scald in 'Anjou' pears. Whereas only 0.3% of control fruit had scald symp-

toms, fumigated fruit had from 14% to 30%. When fruits with scald were subjectively scored for the surface area affected, scores for the fumigated fruit were generally higher than those for control fruit.

Hunter "L" color values for the flesh were reduced in 'Anjou' pears nearly a full "L" unit by fumigation—a consequence of tissue darkening. Although only a 0.5 difference in "L" values is required for human perception (Hunter and Harold, 1987), the darker flesh color of fumigated fruit was not visible.

Although dose of MeBr had little or no consistent influence on the external or internal color of 'Anjou' pears, it did have a significant effect on scald. 'Anjou' fumigated at the highest concentration (48 g·m⁻³) of MeBr developed scald, but the incidence and severity of the disorder were significantly less than at the two lower rates. MeBr fumigation did not affect firmness, SSC, or titratable acidity (data not shown) of 'Anjou' fumigated shortly after harvest.

External and internal color of 'Bosc' pears fumigated shortly after harvest was not influenced by MeBr (Table 1). External color changes would be difficult to see visually because 'Bosc' are russeted. Some pithy brown core was present (range of 10% to 17%), but the visual flesh scores were the same for all treatments immediately after removal from storage.

'Bosc' pears fumigated with MeBr retained firmness better than unfumigated fruit and retention was directly related to the concentration of MeBr. SSC and titratable acid-

ity of 'Bosc' were not affected by MeBr fumigation (data not shown).

Time in storage and ripening period had a distinct influence on quality attributes in both cultivars (Table 1). Consistent and predictable interactions (data not shown) were present between storage and ripening periods and most of the quality attributes. As storage time progressed, less time was required for firmness loss and color changes during ripening.

'Anjou' pears fumigated with MeBr, after 5 months of CA storage, displayed external changes directly related to MeBr treatment (Table 2). In two crop seasons, MeBr-treated pears had lower Hunter color "L" and "b" values. This change in color was evident at the lowest MeBr concentration ($32 \text{ g}\cdot\text{m}^{-3}$) and persisted to the highest one. As with the 'Anjou' treated with MeBr shortly after harvest (Table 1), those treated with MeBr after 5 months of CA storage had more scald (Table 2). The amount of scald (24%) associated with fumigation was the same for pears treated after harvest or after 5 months in CA. Visual ratings for scald were higher with increased amounts of MeBr, but differences were not as distinct with 'Anjou' treated after storage as with those treated shortly after harvest.

External color in 'Bosc' pears from CA storage was not affected by MeBr fumigation (Table 3), as also was the case at harvest (Table 1). There was a distinct reduction in the internal Hunter color, "L" and "b" and hue values for 'Bosc' pears harvested in 1989 and examined in Spring 1990. This reduction in Hunter color values was consistent with an unacceptable brown internal appearance of the pears. Percentage of visual pithy brown core was doubled for all MeBr treatments.

There was no reduction in external or internal Hunter color values for 'Bosc' treated with MeBr in Spring 1991. In addition, no brown core or other internal visual problems were evident regardless of MeBr concentration used. Firmness was higher in MeBr-treated fruit than in the controls (Table 3), although the difference was slight (1.5 N).

Numerous reports are available on the toxic

effects of MeBr fumigation on both external and internal apple quality. Sproul et al. (1976) and Meheriuk et al. (1990) reported external injury to apples in the form of increased scald due to MeBr treatment. In this study, it was clear that the use of MeBr as a fumigant exacerbated scald in 'Anjou' pears fumigated shortly after harvest and after 5 months of CA storage. In either instance, the amount of scald present would significantly reduce marketability. Olsen (1983) reported increased scald in 'Anjou' pears-but its occurrence was not only related to MeBr fumigation but also to fumigation temperature.

A distinct decrease in internal Hunter color values were found for 'Bosc' pears treated with MeBr after 5 months CA storage. This reduction in color values was coupled with an increase in pithy brown core, but these conditions were found only in the crop harvested in 1989. Condition of the pears was very poor and unacceptable for the market. Pears harvested in 1990 had acceptable internal color and no evidence of pith brown core.

Softening was slower in 'Bosc' pears fumigated with MeBr shortly after harvest or after 5 months CA Storage. This slowing of softening may indicate a reduction in the ripening rate. However, no difference in titratable acidity or SSC was observed, and no differences in respiration rates were evident between fumigated and unfumigated pears treated after 5 months CA storage. Olsen (1983) noted these same changes in 'Bosc' pears and determined the changes to be an interaction between MeBr dosage and fumigation temperature.

Careful consideration must be given to the fumigation of winter pears with MeBr. Some form of scald control must be used when 'Anjou' pears are fumigated with MeBr. However, 'Bosc' pears would be good candidates for MeBr fumigation provided pears were in good condition with no advanced physiological problems.

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