

## APPLE WAXING AFTER METHYL BROMIDE FUMIGATION

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### ABSTRACT

Organic methyl bromide (MeBr) residue present in fumigated apples, after waxing, is dependent upon the type of wax used and the time after MeBr exposure. Use of carnauba wax allows the MeBr residue to dissipate faster than does the use of shellac wax. With carnauba wax, the MeBr residue levels were less than 0.001 ppm when apples were waxed 5 days after fumigation. With shellac wax, the residue levels were 0.003 ppm 7 days after fumigation. MeBr residue levels were less than 0.010 ppm using either carnauba or shellac wax 3 days after fumigation. Use of MeBr as a fumigant did not influence the internal or external color, firmness, or soluble solids of 'Delicious' apples regardless of the type of storage (regular or controlled atmosphere) from where the apples were obtained. Fumigated apples from controlled atmosphere storage retained a higher acid content than apples that were not fumigated. The use of either carnauba or shellac wax resulted in a redder 'Delicious' apple.

### INTRODUCTION

Exportation of apples to foreign markets is a major priority of the Washington State apple industry. One of the primary factors restricting export of apples is quarantine barriers established to prevent the spread of codling moth (*Cydia pomonella* L.). MeBr has been used as a fumigant for the disinfestation of apples with varying degrees of success. A major disadvantage of using MeBr is that the high dosage required to eliminate the insect in question can lead to injury to the host fruit. Nevertheless, MeBr is the approved fumigant (56 g/m<sup>3</sup> at 6 or 10 °C for 2 hrs.) for the exportation of apples to foreign markets.

MeBr injury to apples (*Malus domestica* Borkh) has been widely reported, but results have varied for many reasons, including the cultivar, fumigation procedure, and length of time required for the injury to appear (Phillips et al., 1939; Phillips and Monro, 1939; Chapman, 1940; Kenworthy, 1944; Kenworthy and Gaddis, 1946; Claypool and Vines, 1956; Drake et al., 1988; Drake et al., 1990). Phillips and Monro (1939) observed no injury to 'Delicious' apples when treated with MeBr. Kenworthy and Gaddis (1946) observed internal and external injury to 'Delicious' apples treated with MeBr. Drake et al. (1990) reported internal darkening of 'Delicious' apples after exposure to MeBr, but the damage required time to appear and was dependent on dosage, temperature, and time of exposure.

Most of these studies have been with unwaxed apples. One study (Drake et al., 1988) determined that waxing of apples prior to fumigation was not acceptable due to lack of adsorption of the MeBr to and from the wax material. Apples traditionally are waxed to improve their sensory appearance (Schomer and Pierson, 1967; Smock, 1969). The use of wax has been shown to reduce water loss and respiration rate, change the ripening pattern in regard to color, and reduce loss of firmness (Trout et al., 1952; Meheriuk and Porritt, 1972; Bramlage, 1986; Drake and Nelson, 1990). In most instances, the differences due to waxing are dependent upon the cultivar in question.

Recently, the Washington State apple industry has expressed interest in the waxing of apples after MeBr fumigation to improve their appearance for export. This study was conducted to determine the time required after exposure to MeBr for the adsorption and desorption to occur so fruit could be waxed and arrive at foreign markets with no MeBr residue. MeBr residue after waxing with either shellac or carnauba wax and subsequent fruit quality was determined.

## MATERIALS AND METHODS

Unwaxed 'Delicious' apples, size 113, were obtained from a local packinghouse in late October from regular atmosphere (RA) and again in late January from controlled atmosphere (CA). Apples from both types of storage averaged less than 14 lbs. of firmness prior to fumigation. Apples were held at 1 °C until conditioning at 20 °C for 12 hrs. prior to MeBr treatment. All fumigations of MeBr were at 56 g/m<sup>3</sup> for 2 hrs. at 10 °C of exposure and 2 hrs. of aeration. Fumigations were conducted at normal atmosphere pressure in 28.3-liter fiberglass chambers equipped with circulating fans that operated continuously throughout the exposure period. At 0, 1, 3, 5, and 7 days after fumigation, apples were waxed using either shellac (Shield Brite AP40) or carnauba (Shield Brite AP50) wax and dried at 60 °C. After waxing, the apples were boxed with poly liners, returned to cold storage, removed after 30 or 60 days and evaluated.

A sample of 16 apples of each combination of time after fumigation (5), type of wax (2) and replication (3) was evaluated for quality. Eight apples were evaluated immediately after removal from storage; the remaining 8 apples were evaluated after 7 days at ambient temperature. Apples were evaluated for firmness, objective and subjective color, soluble solids content (SSC), titratable acidity, and physiological disorders as previously re-reported (Drake et al., 1990).

Four apples of each combination (time after fumigation, type of wax, and replication) were evaluated for MeBr residue. Organic MeBr residue analyses were conducted using the method of King et al. (1981). Apples used for organic MeBr residue were waxed as described, held in cold storage (1 °C) for 11 days to simulate the time required for shipping to the Far East, and then frozen until analysis. Average values, analysis of variance, and test for significance using the Kruskal-Wallis k-sample test were determined by SAS (SAS Institute, 1985).

## RESULTS AND DISCUSSION

Organic MeBr residue present in apples after waxing is dependent upon the type of wax used and the time after MeBr exposure (Table 1). The use of carnauba wax allows the MeBr residue to dissipate faster than does the use of shellac wax. With carnauba wax, the MeBr residue levels declined rapidly to the point where they were less than 0.001 ppm when apples were waxed 5 days after fumigation and held for an 11-day simulated shipping period.

With shellac wax, the residue levels were still 0.003 ppm when the fruit were waxed 7 days after fumigation and held for 11 days. MeBr residue levels were less than 0.010 ppm using either carnauba or shellac wax 3 days after fumigation and held for 11 days to simulate shipping.

Internal discoloration has been reported when 'Delicious' apples have been fumigated with MeBr (Kenworthy and Gaddis, 1946; Drake et al., 1990). In this study, no internal discoloration of 'Delicious' apples was evident (Table 2). The internal color of apples from RA storage were identical in objective Hunter "L", "b" and hue values and subjective visual values (data not shown) regardless of the use of MeBr as a fumigant or the type or time of waxing. Apples from CA storage were identical in objective Hunter "a" and hue values and subjective visual values. Hunter "L" values were different depending on time of application of wax. Apples from CA not

fumigated or waxed were lighter in color (higher Hunter “L” values) than apples fumigated with MeBr and not waxed. This difference in Hunter “L” is less than one unit (0.7) in value and would not be visible to the human eye (Hunter and Harold, 1987). No other change in Hunter “L” values was evident regardless of fumigation or wax treatment. Type of wax, carnauba or shellac, had no influence on the internal color of 'Delicious' apples.

External color was influenced by the use of MeBr and time of wax application (Table 2). Hunter “L” values increased and Hunter “a” values decreased as time of wax application was delayed for apples from RA storage, but no change in hue values was evident. This change in Hunter “a” values would indicate a slightly redder apple for the fruit fumigated with MeBr, but not waxed. Fruit fumigated with MeBr and waxed were similar in red color to the fruit not fumigated and not waxed. In addition, fumigated and waxed fruit from RA had higher Hunter “L” values as wax application was delayed from 1 to 7 days. This change in Hunter “L” values would indicate a lighter red color. Hunter “L” values for apples from CA storage did not change with fumigation or wax application, but there was a change in Hunter “a” and hue values. Apples from CA fumigated and not waxed were redder than fruit from the other fumigation and wax treatments indicated in “a” and hue values. Little or no color difference was evident for fruit from CA fumigated and waxed at various times. The appearance of red color was enhanced with the use of wax regardless of the type of wax (carnauba or shellac). This difference in red color was evident for apples from both RA and CA storage and could be considered an economic advantage. The color change due to waxing was present when both Hunter “L” and “a” values were considered.

Firmness values of RA fruit were not influenced by the use of MeBr or delay in wax application (Table 3). Apples from RA had very low firmness values, but even this weak fruit did not react to fumigation or time of wax application. The use of wax, either carnauba or shellac, did not aid in firmness retention. Apples from CA were firmer at the start of the study, but the post-treatment results were similar to the fruit from RA. Firmness values did not change with fumigation, delay of wax application, or with the use of wax. Soluble solids remained constant for apples from both RA and CA storage regardless of fumigation, delay in wax application, or type of wax used. Acid retention is a major consideration in the maintenance of apple flavor. Neither the use of MeBr, delay in wax application, or type of wax influenced acid retention of 'Delicious' apples from RA storage. Acid retention for apples from CA storage was influenced by the use of both MeBr fumigation and wax application. This difference in acid content (0.02) is small, but significant, when the usually low acid content of this cultivar is considered. Type of wax did not influence acid retention for apples from either RA or CA storage.

## CONCLUSION

'Delicious' apples can be fumigated, then waxed, and arrive at ports of entry with extremely low levels of MeBr residue (<0.010 ppm). The type of wax used has an influence on the retention of MeBr. Carnauba waxed apples lose MeBr at a more rapid rate than apples waxed with shellac. The MeBr residue of apples waxed with carnauba is less than 0.001 ppm after 3 days plus 11 days of simulated shipping after fumigation, whereas apples waxed with shellac require 2 more additional days to reach the same residue level. The apples used in this study from both RA and CA storage were very weak (as indicated by firmness values), but no loss of firmness, soluble solids, or acid retention was evident when apples were fumigated or wax application was delayed. In addition, even with the use of weak fruit, the internal color was not influenced by the use of MeBr. External color of 'Delicious' apples was enhanced with the use of either carnauba or shellac wax.

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Table 1. Organic bromide residues in 'Delicious' apples fumigated with 56 g/m<sup>3</sup> of methyl bromide for 2 hrs. at 10°C, followed by 2 hrs. aeration, then waxed with either shellac or carnauba wax at 1, 3, 5, or 7 days after methyl bromide treatment.

Treatment	Rep.	Organic bromide residues (ppm) <sup>xy</sup>				
		No wax after aeration	Waxed after 1 day	Waxed after 3 days	Waxed after 5 days	Waxed after 7 days
No wax	1	0.003	—	—	—	—
	2	0.002	—	—	—	—
	3	<0.001	—	—	—	—
	X ± SD	0.002-0.001	—	—	—	—
Shellac wax	1	—	0.051	0.005	0.003	0.003
	2	—	0.008	0.008	0.004	0.002
	3	—	0.005	0.005	0.003	0.003
	X ± SD	—	0.032-0.022	0.006-0.002	0.003-0.006	0.003-0.006
Carnauba wax	1	—	0.008	0.004	<0.001	<0.001
	2	—	0.016	0.002	<0.001	<0.001
	3	—	0.042	0.006	0.001	<0.001
	X ± SD	—	0.022-0.018	0.004-0.002	<0.001	<0.001

Table 2. Internal and external Hunter color of 'Delicious' apples as influenced by methyl bromide fumigation, time of wax application, and type of wax.

Treatment	Internal color						External color					
	"L"		"b"		hue		"L"		"a"		hue	
	RA	CA	RA	CA	RA	CA	RA	CA	RA	CA	RA	CA
<b>MeBr/Wax</b>												
MeBr, no wax	74.8a <sup>1</sup>	74.8cd	23.3a	23.3a	90.0a	92.9a	32.0d	37.9a	24.3a	26.4a	19.1a	23.2bc
MeBr, wax after 1 day	73.3a	75.2bcd	23.2a	23.2a	88.2a	93.2a	32.9cd	39.2a	21.6b	24.6b	19.8a	24.8ab
MeBr, wax after 3 days	75.5a	75.7bcd	23.7a	23.1a	90.3a	93.3a	33.5abc	39.1a	21.8b	24.4b	19.2a	24.8ab
MeBr, wax after 5 days	75.5a	75.8bcd	23.8a	22.9a	90.7a	93.7a	34.0ab	38.5a	21.7b	24.1b	19.2a	24.1b
MeBr, wax after 7 days	74.7a	76.1abc	23.7a	22.7a	90.6a	94.2a	34.6a	38.7a	21.9b	24.3b	19.6a	23.7bc
<b>Type of wax</b>												
No wax	74.7a	75.2a	23.5a	24.2a	90.3a	93.2a	31.7c	37.9b	23.6a	25.5a	19.3a	24.1a
Shellac	74.0a	75.7a	23.5a	23.0a	89.5a	93.7a	33.2b	38.2b	22.2b	24.3a	19.2a	24.2a
Carnauba	75.1a	75.7a	23.7a	23.0a	90.4a	93.5a	34.2a	39.6a	21.3c	24.4a	19.3a	24.5a

<sup>1</sup> Means followed by the same letter in a column, within treatments, are not significantly different (P>0.05).

Table 3. Firmness, soluble solids, and acid content of 'Delicious' apples as influenced by methyl bromide fumigation, time of wax application, and type of wax.

Treatment	Firmness (lbs.)		Soluble solids (%)		Titratable acidity (% malic)	
	RA	CA	RA	CA	RA	CA
<b>MeBr/wax</b>						
No MeBr, no wax	92.a <sup>2</sup>	11.5a	13.0a	13.6ab	0.22a	0.24b
MeBr, no wax	9.5a	11.7a	12.8a	13.7ab	0.24a	0.26a
MeBr, wax after 1 day	9.2a	11.4a	12.9a	13.9a	0.24a	0.26a
MeBr, wax after 3 days	9.4a	11.6a	12.8a	13.8ab	0.24a	0.26a
MeBr, wax after 5 days	8.8a	12.3b	12.8a	13.5b	0.24a	0.26a
MeBr, wax after 7 days	8.7a	12.3b	12.5a	13.3c	0.24a	0.27a
<b>Type of wax</b>						
No wax	9.4a	11.6a	12.9a	13.6a	0.23a	0.25a
Shellac	8.9a	12.0a	12.8a	13.6a	0.24a	0.27a
Carnauba	9.1a	11.8a	12.7a	13.6a	0.24a	0.26a

<sup>2</sup> Means followed by the same letter in a column, within treatments, are not significantly different (>0.05).