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CT Product and its Variation in Varieties of Commodities Fumigated with Methyl Bromide

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Abstract: CT products and their variations in varieties of commodities fumigated with methyl bromide (MB) were examined with a few varieties of apples, apricots, cherries, pears, plums, nectarines and walnuts including fruits stored for different periods and harvested in different years. The result showed that (1) the maximum variation of CT products between varieties was 33.0% in walnuts, 9.4% in apples, 6.6% in cherries, 6.0% in pears, 5.7% in plums, 5.2% in nectarines and 2.2% in apricots, respectively and higher variation (9.4%) among varieties of perishable commodities was observed between 'Alps Otome' and 'Mutsu' apples, and that (2) variations of CT products between storage fruits and non-storage fruits were +0.9~+4.1% in plums, +0.1%~+1.1% in nectarines, -0.3~-2.0% in pears and -0.9~+1.3% in apples, respectively and higher variation (4.1%) was observed on 'Ooishi Wase' plums, and that (3) variations of CT products in fruits harvested in different years were -2.3~+4.3% in apples, -1.6~+1.1% in nectarines and higher variation (4.3%) was observed on 'Alps Otome' apples, and that (4) the maximum variation of 9.4% (between 'Alps Otome' and 'Mutsu' apples) in 6 perishable commodities was larger than that 4.1% ('Ooishi Wase' plums) and of 4.3% ('Fuji' apples) from the test on influences of different storage periods and different harvest years of fruits on the CT product. The data suggested that the variation of the CT product within the variety was smaller than that between varieties of commodities. Since the variation of as much as 33.0% between walnut varieties was too much variation to achieve a quarantine security, further tests for a new fumigation schedule would be required for additional varieties.
Key words: methyl bromide, fumigation, sorption, CT product, variation, variety, apricots, apples, cherries, pears, plums, nectarines, walnuts

Introduction

MONRO (1969) and FAO (1983) described that a most important factor affecting the action of a fumigant such as methyl bromide (MB) is the phenomenon known as sorption covered three types of phenomena of absorption, chemisorption and adsorption with physical and chemical process, and that the sorptive amount of gas depends on fumigation items or commodities and the amount can be estimated and identified by calculating of the CT product which is known as an indicator of insecticidal efficacy in routine fumigation.

There are some reports on MB sorption and possible major factors which cause the different amount of gas sorption in different varieties of the same fruit or in different fruit. The LD_{50}'s for the codling moth eggs, *Cydia pomonella* on 'Summer Grand' variety of nec-

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tarines were significantly more susceptible than those on other varieties of 'May Grand', 'Firebrite', 'Red Diamond', 'Spring Red' and 'Fantasia' (YOKOYAMA *et al.*, 1987). MB residues were greater in oranges and tangerines than in grapefruit at any dose tested and the fruit surface area to volume ratio was a possible major factor in the amount of MB absorbed (KING & BENSCHOTER 1991). Differences were found in sorption of MB to cherry between varieties and between seasons (MAINDONALD *et al.*, 1992). KAWAKAMI *et al.* (1998) reported that the maximum difference of the CT product between varieties was 7% in nectarines ('Shuhou' and 'Fantasia') and 12% in apples ('Tsugaru' and 'Mutsu') and gas decline patterns during fumigation were also different from 3 varieties of nectarines and 13 varieties of apples, and that the difference in nectarines may be attributable to 'Shuhou's larger surface area based on rough skin and the difference in apples may take part in the action of MB/oily skin and soft pulp interaction.

These data clearly suggest that the sorptive amount of MB gas varies not only in species of fruit but also in varietal characteristics of the same fruit, and that the sorptive amount of MB may also vary according to other conditions of storage periods after harvest and harvest year of fruit.

We, therefore, conducted the test for confirmation of the variation of the CT product in 18 varieties of 7 commodities and for influences of different storage periods and different harvest years of apples, nectarines, pears and plums on the variation of the CT product.

Materials and Methods

Test Fruits

Test fruits were obtained from local packing houses in production areas. The following commodities and their varieties were used for the tests in 1997, 1998 and 1999. These fruits were stored at 0℃ (apples), 5℃ (apricots cherries, pears, plums and nectarines) and room temperature (walnuts) until fumigation and then stored at each fumigation temperature at the Research Division, Yokohama Plant Protection Station, Ministry of Agriculture, Forestry and Fisheries.

Commodity	Variety	Production area	Harvest time
Apples	Alps Otome	Nagano	Sept '99
	Mutsu	Aomori	Oct '98, '99
	Fuji	Aomori	Nov '98, '99
	Kinsei	Aomori	Nov '98, '99
Apricot	Harcot	Nagano	July '99
	Shinsyu Oomi	Nagano	July '99
Cherries	Beni Shuhou	Yamagata	July '99
	Napoleon	Yamagata	July '99
	Satou Nishiki	Yamagata	June '99
Pears	La France	Yamagata	Nov '99
	Bartlett	Nagano	Sept '99
Plums	Sordum	Yamagata	July '99
	Ooishi Wase	Yamagata	June '99

Nectarines	Fantasia	Fukushima	Aug '97, '99
	Shuhou	Fukushima	Sept '97, '98, '99
	Flavortop	Nagano	Aug '97, '99
Walnuts	Shinrei	Nagano	Nov '99
	Oni Gurumi	Iwate	Oct '99

Fumigation

Fumigation was conducted in a 29.5 liter fiber-glass fumigation box (26.0cm × 28.0cm × 41.0cm in size) equipped with circulation fan, ventilation apparatus, ports for gas application and sampling, manometer and temperature probes. Each variety of fruit was weighed by a top-loading digital balance (LIBROR EB-3200D, Shimadzu) with special attention to be adjusted fruit loading and then these fruits were placed in the fumigation box. The following treatment schedules were applied for MB fumigation; nectarines, apricot and plums: 48g/m^3 for 2 hours at 20℃ with 0.14kg/*l* loading, for Cherries: 64g/m^3 for 2 hours at 10℃ with 0.14kg/*l* loading, for apples and pears: 56g/m^3 for 2 hours at 10℃ with 0.16kg/*l* loading and for walnuts: 56g/m^3 for 4 hours at 20℃ with 0.14kg/*l*, loading respectively.

MB was introduced with a gas-tight syringe and the gas circulation fan was kept on for the first 15 minutes and then used automatic timer (on: 1 minute, off: 3 minutes). Gas concentrations were measured with gas chromatograph (FID, GC-14B, Shimadzu) at time intervals of 10, 30, 60, 90 and 120 minutes (and 180 and 240 minutes in walnuts) after injection of MB. Air temperature in the fumigation box was also monitored with a multi-channel automatic temperature recorder (Hybrids recorder AH, Chino) during fumigation. After fumigation, the gas was exhausted for 1 hour using the ventilation apparatus. Each variety was fumigated with 2 to 4 replicates.

Calculation of CT Product

The CT product was calculated similarly to the method described by MONRO (1969) with gas concentration records measured in 10, 30, 60, 90 and 120 minutes in apples, apricots, cherries, nectarines, pears, plums and walnuts, and in 180 and 240 minutes in walnuts after MB injection.

Measurements of Weight, Firmness, Sugar Content and Acidity of Fruit

Weight, specific gravity, firmness, sugar content and acidity of fruits were measured with 5 to 10 fruits of nectarines, apples and pears. Those fruits were measured with a top-loading digital balance (LIBROR EB-3200D, Shimadzu) for weight, with a hardness tester (KM type, Fujiwara) for firmness and with a temperature-compensated digital refractometer (DX-55, Atago) for sugar content, respectively. Specific gravity was determined by replacing water with fruit. Acidity was determined with a digital acid mater (ACILYZER model 5, Fujihira) for nectarines and with titration method as the amount of malic acid in 100 m*l* of the solution of apple and pears.

Results and Discussion

Variations of CT products among Varieties of Commodities

Table 1 shows CT products and their variations between varieties of apples, apricots, cherries, nectarines, pears, plums and walnuts. The maximum variation of CT products between varieties was 33.0% in walnuts, 9.4% in apples, 6.6% in cherries, 6.0% in pears, 5.6% in plums, 5.2% in nectarines and 2.2% in apricots, respectively. The highest variation of 9.4% among 15 varieties in 6 perishable commodities was observed between 'Alps Otome' and 'Mutsu' apples, while the variation in varieties of apricots, cherries, nectarines, pears, and plums was 6.6～2.2%.

The variation between 'Shinrei' and 'Oni Gurumi' walnuts was as much as 33.0%. Especially residual gas concentration at the end of fumigation was extremely low in 'Oni Gurumi' variety. The result supported the report (HARTSELL *et al.*, 1991) that whole walnuts of 'Hartley', 'Payne' and 'Franquette' sorbed 79.6% of the MB applied because of high MB

Table 1. CT products and their variation rates for varieties of apricots, apples, cherries, nectarine, pears, plums and walnuts in methyl bromide fumigation[1] conducted in 1999.

Commodity	Variety	CT product ($g \cdot h/m^3 \pm SD$)	Variation[2] (%)
Apricots	Harcot	76.8 ± 0.4	-
	Shinsyu Oomi	75.1 ± 0.5	2.2
Plums	Sordum	86.3 ± 1.0	-
	Ooishi Wase	81.4 ± 0.9	5.7
Nectarines	Fantasia	73.4 ± 0.3	-
	Shuhou	69.7 ± 0.4	5.0
	Flavortop	69.6 ± 0.5	5.2
Cherries	Beni Shuhou	111.8 ± 0.4	-
	Satou Nishiki	104.4 ± 1.9	6.6
	Napoleon	104.4 ± 0.9	6.6
Pears	La France	122.6 ± 1.0	-
	Bartlett	115.3 ± 0.4	6.0
Apples	Mutsu	121.8 ± 1.0	-
	Fuji	119.5 ± 1.0	1.9
	Alps Otome	110.4 ± 0.5	9.4
Walnuts	Shinrei	56.4 ± 0.9	-
		(85.0 ± 1.6)[3]	-
	Oni Gurumi	37.8 ± 0.6	33.0
		(57.3 ± 1.4)[3]	(32.6)[3]

[1] Fumigation schedules: apricots, plums and nectarines ($48g/m^3$ of MB for 2 hrs at 20℃ with $0.14kg/l$ loading), cherries ($64g/m^3$ of MB for 2 hrs at 10℃ with $0.14 kg/l$ loading), apples and pears ($56g/m^3$ of MB for 2 hrs at 10℃ with $0.16kg/l$ loading) and walnuts ($56g/m^3$ of MB for 4 hrs at 20℃ with $0.14kg/l$ loading).

[2] Variation (%) = 100 [1-(minimum CT product/maximum CT product)].

[3] Data from 4 hours fumigation.

sorptive properties of walnuts. If the treatment schedule was established with 'Shinrei' variety, additional tests would be required for 'Oni Gurumi' variety to confirm complete mortality of the pest.

Influence of Storage Periods of Fruit on CT products

Table 2 shows CT products and their variations in each variety of apples, nectarines, pears and plums stored for different periods after harvest. Variations of the CT product were +0.9~+4.1% in plums, -0.9~+1.3% in apples, +0.1%~+1.1% in nectarines and -0.3~-2.0% in pears, respectively and the higher variation of 4.1% was observed on 'Ooishi Wase' plums. Table 3 shows the data of weight, specific gravity, firmness, sugar content

Table 2. CT products and their variations in varieties of apples, pears, plums and nectarines stored for different periods on methyl bromide fumigation.[1)]

Commodity	Variety	Storage period (day)	Fumigation temperature (℃)	CT product ($g \cdot h/m^3 \pm SD$)	Variation[2)] (%)
Nectarines[3)]	Shuhou	0	19.6 (19.4-19.8)	70.4 ± 0.3	-
		20	18.7 (18.4-19.0)	70.5 ± 0.7	+0.1
		30	18.5 (18.3-18.6)	71.2 ± 0.4	+1.1
Plums[4)]	Sordum	0	19.4 (19.0-19.7)	86.3 ± 1.0	-
		14	18.2 (18.1-18.5)	87.1 ± 0.2	+0.9
		28	20.2 (20.1-20.7)	88.2 ± 0.5	+2.2
	Ooishi Wase	0	20.0 (19.8-20.3)	81.4 ± 0.9	-
		14	19.9 (19.4-20.4)	84.7 ± 0.6	+4.1
		28	19.7 (19.3-20.1)	84.5 ± 0.4	+3.8
Pears[4)]	La France	0	10.3 (10.0-10.6)	122.6 ± 0.9	-
		20	9.7 (9.6- 9.9)	120.2 ± 0.5	-2.0
	Bartlett	0	10.4 (9.6-11.1)	115.3 ± 0.4	-
		20	9.9 (9.8-10.1)	114.9 ± 1.1	-0.3
Apples[3)]	Mutsu	0	9.7 (9.4-10.0)	118.2 ± 3.2	-
		60	9.8 (9.6-10.0)	118.3 ± 0.5	+0.1
		120	9.9 (9.7-10.1)	119.7 ± 0.4	+1.3
	Fuji	0	10.5 (10.5-10.6)	112.0 ± 0.3	-
		60	9.9 (9.7-10.0)	111.0 ± 0.2	-0.9
		120	9.9 (9.6-10.2)	112.2 ± 0.5	+0.2
	Kinsei	0	9.4 (9.2- 9.8)	103.2 ± 1.2	-
		60	9.8 (9.6- 9.9)	104.1 ± 0.5	+0.9
		120	9.9 (9.6-10.2)	103.9 ± 0.5	+0.7
Apples[4)]	Mutsu	0	9.7 (9.4-10.0)	121.8 ± 1.0	-
		20	10.2 (10.1-10.3)	122.5 ± 1.5	+0.6

[1)] Fumigation schedules: plums and nectarines ($48g/m^3$ of MB for 2 hrs at 20℃ with $0.14kg/l$ loading), apples and pears ($56g/m^3$ of MB for 2 hrs at 10℃ with $0.16kg/l$ loading)

[2)] Variation (%) = 100 [1-(CT product from storage fruit/CT product from non-storage fruit)].

[3)] The test was conducted in 1998.

[4)] The test was conducted in 1999.

Table 3. Weight, specific gravity, firmness, sugar content and acidity of apples, pears and nectarines stored for different period.

Commodity	Variety	Storage period (day)	Weight (g/fruit)	Specific gravity (kg/*l*)	Firmness (kg)	Sugar content (Brix%)	Acidity (g/100m*l*)
Nectarines[2]	Shuhou	0	283	0.96	1.59	9.5	0.9[1]
		20	276	0.96	0.99	10.0	0.8[1]
		30	261	0.92	1.11	9.2	0.8[1]
Pears[3]	La France	0	285	0.99	1.44	13.9	0.3
		20	280	1.02	1.35	14.4	0.2
	Bartlett	0	252	0.97	2.88	10.3	0.3
		20	330	0.98	2.86	11.5	0.3
Apples[2]	Mutsu	0	338	0.84	2.61	12.0	0.4
		60	339	0.85	2.48	11.6	0.3
		120	339	0.84	2.50	11.8	0.4
	Fuji	0	296	0.84	2.56	14.1	0.3
		60	297	0.84	2.37	14.6	0.2
		120	296	0.83	2.42	13.5	0.2
	Kinsei	0	337	0.82	2.43	15.5	0.3
		60	339	0.85	2.28	15.2	0.1
		120	338	0.84	2.27	14.3	0.1
Apples[3]	Mutsu	0	416	0.83	2.64	11.6	0.5
		20	418	0.84	2.69	12.0	0.5

[1] Unit : %

[2] The test was conducted in 1998.

[3] The test was conducted in 1999.

and acidity of apples, nectarines and pears. A slight reduction of firmness in all commodities and of weight in nectarines, and higher sugar content and lower acidity in 'La France' pears were confirmed on fruits during storage, respectively. However, it was not clear on influence of these factors on the variaiton of the CT product.

Influence of Harvest Year of Fruit on CT products

Table 4 shows CT products and their variations in varieties of nectarines and apples harvested in different year of 1997, 1998 and 1999. Variations of the CT product between in 1997 and 1998 or 1999 were -2.3～+4.3% in apples and -1.6～+1.1% in nectarines, respectively and higher variation of 4.3% was observed on 'Fuji' apples.

The result of the test showed that the maximum variation of 9.4% (between 'Alps Otome' and 'Mutsu' apples) among 15 varieties in 6 perishable commodities was larger than that of 4.1% ('Ooishi Wase' plums) and of 4.3% ('Fuji' apples) from the test on influences of different storage periods and different harvest years of fruits on the CT product. The data suggested that the variation of the CT product within the variety was smaller than that between varieties of commodities, and that since the variation of as much as

Table 4. CT products and their variations in varieties of apples and nectarines harvested and fumigated with methyl bromide[1] in 1997, 1998 and 1999.

Commodity	Variety	Year tested	CT product ($g \cdot h/m^3 \pm SD$)	Variation[2] (%)
Nectarines	Fantasia	1997	72.6 ± 1.8	-
		1999	73.4 ± 0.3	+1.1
	Shuhou	1997	69.7 ± 0.5	-
		1998	70.4 ± 0.3	+1.0
		1999	69.7 ± 0.4	0.0
	Flavortop	1997	70.7 ± 1.2	-
		1999	69.6 ± 0.5	-1.6
Apples	Mutsu	1997[3]	118.1 ± 0.3	-
		1998	118.2 ± 3.2	+0.1
		1999	121.8 ± 1.0	+3.1
	Fuji	1997[3]	114.6 ± 0.5	-
		1998	112.0 ± 0.3	-2.3
		1999	119.5 ± 1.0	+4.3
	Alps Otome	1997[3]	106.1 ± 1.5	-
		1999	110.4 ± 0.5	+4.1

[1] Fumigation schedules: nectarines ($48g/m^3$ of MB for 2 hrs at 20℃ with $0.14kg/l$ loading) and apples ($56g/m^3$ of MB for 2 hrs at 10℃ with 0.16 kg/l loading).

[2] Variation (%) = 100[1-(CT product from fruit in 1998 or 1999/CT product from fruit in 1997)].

[3] Data from KAWAKAMI *et al.* (1998).

33.0% of the CT product between varieties in walnuts was too much variation to achieve a quarantine security, further tests for a new fumigation schedule would be required for additional varieties.

On the other hand, MIZOBUCHI *et al.* (2001) reported that no significant difference was observed in the susceptibility of the peach fruit moth eggs to MB fumigation between 'Alps Otome' and 'Mutsu' apple in both the LC_{50}'s and the LD_{50}'s from the dose-response test (6 doses of MB for 2 hours at 15℃ with $0.16kg/l$ loading). However, 95% confidential limits between apple varieties were slightly overlapped with the difference of a dose of $0.1mg/l$ each other in the LD_{50}'s. The variation of 9.4% of the CT product between 'Alps Otome' and 'Mutsu' apples was observed on both apple varieties fumigated at $56g/m^3$ for 2 hours at 10℃ with $0.16kg/l$ loading, which was almost the same schedule for the dose-response test conducted by MIZOBUCHI *et al.* (2001) except for applied dose.

Taking account of the relationship between the susceptibility of the pest and the maximum variation of 9.4% of the CT product among 15 varieties in 6 perishable commodities, there would be a possibility of difference in efficacy if the variation of CT product is higher than 9.4%, while the variation would not affect on the efficacy if it is less than

9.4%. Therefore, the variation of 9.4% of the CT product between varieties of commodities would be considered as an indicator of fumigation efficacy in the CT product comparison test with different varieties of commodities in MB fumigation.

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和 文 摘 要

臭化メチルくん蒸における果実品種間のCT値及びその変動

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アンズ，リンゴ，サクランボ，洋梨，スモモ，ネクタリン及びクルミ核子を臭化メチル検疫処理基準でくん蒸し，各品種のCT値及び品種間におけるCTの変動並びに収穫後の低温保管期間や異なる年に収穫された果実がCT値に及ぼす影響について調査した。その結果，(1)各品種におけるCT値の最大差はクルミ核子で33.0%，リンゴで9.4%，サクランボで6.6%，洋梨で6.0%，スモモで5.6%，ネクタリンで5.2%，アンズで2.2%であった。果実類ではリンゴの“アルプス乙女”と“陸奥”の間で最大9.4%の差が認められた。(2)異なる期間低温に保管した果実と保管しない果実間のCT値の変動幅はネクタリンで+0.1～+1.1，スモモで+0.9～+4.1%，洋梨で−0.3～−2.0%及びリンゴで−0.9～+1.3で，変動差はスモモの大石早生が4.1%で最も大きかった。(3)異なる年に収穫されたリンゴ及びネクタリン果実間のCT値の変動幅差はリンゴで−2.3～+4.3%，ネクタリンで−1.6～+1.1%で，変動差はリンゴの“フジ”の4.3%が最も大きかった。(4) 6果実，15品種間における最大の変動差の9.4%（リンゴの“アルプス乙女”と“陸奥”の間）は，異なる期間低温に保管した品種でみられた最大の変動差の4.1%（スモモの“大石早生”）及び異なる年に収穫された品種でみられた最大の変動差の4.3%（リンゴの“フジ”）よりも大きかった。このことは，CT値の変動は個々の品種内の変動よりも品種間の変動の方が大きいことを示している。クルミ核子の品種間における33.0%の変動差は十分な殺虫効果が得られない可能性があるので，品種を追加する場合は新たな試験が必要であろう。

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