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Application of ethyl formate with nitrogen in controlling fruit and vegetable insect pests in perishable commodities

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ABSTRACT

Ethyl formate fumigation, as an alternative of methyl bromide has been developing and commercializing on exported and imported fruits and vegetables in Korea. Fumigation with cylinderized ethyl formate, with relatively short exposure fumigation time, shows effectiveness against target pest and less damage to the commodities than methyl bromide. However, to expand its commercial use to various commodities, costs of fumigant and fumigation need to be competitive to current methyl bromide treatment. In this paper, we report that new application technology of ethyl formate (Fumate) was applied with specially designed vapourizer with nitrogen as a carrier gas. This new technology showed reduce fumigation costs and was found be safe to fumigator as well as protect ozone layer and resulted in reduced greenhouse gas (carbon dioxide) emission.

Key words: Ethyl formate, Fruit and vegetable fumigation, Nitrogen, Quarantine

Methyl bromide (MeBr) is a fumigant which is broadly used in quarantine and pre-shipment (QPS) in South Korea. However, due to ozone depletion properties, it has been slowly replaced by other chemicals such as ethyl formate (EF), phosphine gas (PH_3) and combination treatment EF with PH_3, which was recently used on imported pineapples in Korea. Moreover, MeBr fumigation has revealed acute and chronic health impact on fumigators and related workers during fumigation and post-fumigation process especially at low temperature (< 13°C) because MeBr slowly released from fumigated commodities at cooling storage and packing place and due to inadequate ventilation process. For this reason, Animal and Plant Quarantine Agency in Korea recommended safety guidelines, such as extension of aeration time and improving ventilation facilities, etc. to fumigator and related worker.

Ethyl formate (EF), one of the alternatives, has been developed as stored dry fruit fumigant in Australia, and its successful use had been reported in Australia and South Korea since 1980 (Agarwal et al., 2015, Lee et al., 2016). The advantage of use of EF is its of short fumigation period, low toxicity on mammals and environments, and rapid breakdown with no residues (Haritos et al., 2003; Lee et al., 2016). Moreover, The Food and Drug Administration (FDA, 2004) has reviewed the use of EF as a flavouring agent and has generally recognized it as safe (GRAS). Though high dosage of EF treatment caused slight phytotoxic on some fresh commodities like cut flower and strawberry, properly adjusted treatment could prevent damage of commodity (Agarwal et al., 2015). Fumigation with cylinderized EF, which was commercialized in Korea, shows effectiveness against target pest in various perishable commodities, and commercial acceptance in terms of relatively similar fumigation time and less damage to the commodities than MeBr. However, to expand its commercial use in future, costs of fumigant and fumigation need to be competitive to current MeBr. Liquid EF with nitrogen gas operated vapourizer was applied on export apples for eradicating eucalyptus weevil, *Gonipterus platensis* in Australia (Agarwal et al., 2015). Herein, we introduced this new application technology of ethyl formate (Fumate) in Australia and South Korea, operated with specially designed vapourizer with nitrogen, as safe carrier gases, and was evaluated on imported oranges. This new EF

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Table 1 Ethyl formate applied with specially designed vapourizer with N_2 as safe carrier gas on imported oranges (29% loading ratio, w/v) against four target pests

Trt. (5 ± 1ºC)			Mortlity (Total dead No./Total tested No.)							
Application	Applied dose (g/m^3)	Time (h)	CMB		TSM		CA		GPA	
			Eggs	Nymph + Adult	Nymph	Adult	Nymph	Adult	Nymph	Adult
EF with N_2 using special vapourizer	34.2	4	-	100% (156/156)	-	-	-	-	-	-
	43.2	4	-	100% (163/163)	100% (680/680)	100% (85/85)	100% (470/470)	100% (140/140)	100% (660/660)	100% (415/415)
	68.5	4	-	100% (167/167)	100% (720/720)	100% (85/85)	100% (620/620)	100% (210/210)	10% (490/490)	100% (310/310)
	71.1	4	100% (334/334)	100% (150/150)	-	-	-	-	-	-

CMB, Citrus mealybug; GPA, green peach aphid; CA, cotton aphid; TSM, two-spotted mite

application technology could promote to replace the current MeBr use and high cost of cylindered EF fumigation.

MATERIALS AND METHODS

Fumigants

Fumate (Ethyl formate 99%) was received from Safefume Inc. South Korea and is under the registration process in Australia and South Korea.

Insects and commodity

Citrus mealybug (CMB, *Planococcus citri* Risso) was reared at laboratory condition –25°C temperature with 16:8[L:D]h photo period. Other insects, green peach aphid [GPA, *Myzus persicae* (Sulzer)] and cotton aphid (CA, *Aphid gossypii* Glover) were reared on hot pepper (*Capsicum* sp.) plants, and two-spotted mites [TSM, *Tetranychus urticae* (Koch)] was reared on bean plants at same rearing conditions. At the completion of the 4 h fumigation, the treated insect samples were removed from metal chamber and reared at 25 ± 2 °C and 55 ± 5% r.h. The mortality of egg, nymph and adult were noted after storage in incubator for 24 and 72 h at 25 ± 2°C. For assessment of phytotoxicity, fumigated imported oranges (navel) were stored 3 different storage conditions (5, 15, 5→15°C) for 2 weeks and sugar content (%), redness ratio (Hunter a^*/b^*), the index (0–5 scales) of external phytotoxic damage were measured.

EF vapourizer application with nitrogen as safe carrier gas

Small scale EF fumigation on imported oranges was performed in metal fumigation chamber (0.5 m^3, 29% f.r w/v of fruits) located in sites of Animal and Plant Quarantine Agency (QIA). Two schedule doses (35 and 70 g/m^3) of EF was vapourized with heated N_2 gas through the nitrogen heater, which fitted in vapourizer (temperature: 65 ± 5°C, N_2 gas pressure: 2.5 ± 5 bar) and discharged through the stainless gas line into the metal chamber. Imported oranges were fumigated for 4 h at 5°C. Concentration of EF gas was monitored by GC-FID and gas concentration collected at time interval of 1, 2 and 4 h in chamber was calculated by equation. At the completion of the 4 h fumigation, the metal chambers were opened and aerated for 1 h in a 20 ft container.

RESULTS DISCUSSION

Efficacy of ethyl formate on tested pest and assessment of phytotoxic damage on imported orange

The efficacies of 4 different small scale applications of EF using vapourizer to CMB, TSM, CA and GPA are shown in Table 1. Based on current applied dose (70 g/m^3) of EF, phytotoxic damage on imported oranges was accessed and results are given in Table 2.

CONCLUSION

In this trial, we have evaluated four different small scale fumigation of EF applied specially designed EF vapourizer with nitrogen on imported oranges, which is mostly fumigated with MeBr in Korea. With regard of these results, the 4 h fumigation applied 70 g/m^3 ethyl formate with nitrogen, which has an important role in terms of non-flammable fumigation conditions and better air circulations in fumigation chamber, could be a competitive to MeBr on imported oranges

Table 2 Assessment of phytotoxic damages on imported oranges exposed to 70 g/m^3 of ethyl formate applied EF vapourizer with N_2 as safe carrier gas for 4 h at 5±1°C, 14 d after treatment

Dosage (g/m^3)	Fumigation time (h)	Storage condition	Sugar content ± SE (%)	Redness ratio[2]	External damage[3]
Untreated		L.T.	13.0±0.4 [ab]	0.42[a]	0
	-	R.T.	12.8±0.2 [a]	0.46 [a]	0
		L.T.→ R.T.	13.3±0.6[ab]	0.47 [a]	0
Ethyl formte (70 g/m^3) with N_2		L.T.	12.5±0.4 [a]	0.38 [a]	0
	4	R.T.	12.6±0.3 [a]	0.43 [a]	0
		L.T.→ R.T.	11.2±0.3[b]	0.34 [a]	0

[1]Storage conditions: L.T (Low temperature, 5±1°C), R.T. (Room temperature, 15±5°C); [2]Redness ratio = Hunter *a** / *b**; [3]Damage score: 0 (none), 1 (slight), 2 (moderate), 3 (severe); [4]Means in a column followed by same letter are not significantly different at 5% level

in respect of efficacy and phytotoxicity as well as environmental protection and improving worker safety. To expand its commercial use, this new technology, operated with specially designed vapourizer, could be better potential option than current liquefied CO_2 with EF formulation in cylinder in terms of cost and less CO_2 emissions in atmosphere.

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