COMMERCIAL APPLICATION OF TWO ALTERNATIVES TOMETHYL BROMIDE FUMIGATION ON IMPORTED PINEAPPLE: PHOSPHINE AND A MIXTURE OF ETHYL FORMATE ANDPHOSPHINE

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Introduction: Methyl bromide (MB) has been widely used for rapid fumigation to control various insect pests for quarantine and pre-shipment purposes. However, MB is an ozone depleting substance (ODS), and thus is being phased out under the international plant protection convention(IPPC). In South Korea, alternative fumigants such as ethyl formate (EF), phosphine (PH_3) and mixtures of EF and PH_3 have been developed and commercialized for use on some perishable commodities, but not yet on pineapple. Pineapple-borne pests are particular difficult to control when they enter cracks on the surface of pineapple fruit. In previous small scale studies, we showed that two alternative fumigation strategies were effective: PH_3 gas which completely controlled all stages of citrus mealybug(*Planoccous citri*) after 24hr fumigation at 8℃; and an EF+PH_3 mixture, which reducing fumigation time to 4hr. Herein, we show the cases of commercial success of these two alternatives to MB fumigation in terms of efficacy in eradicating citrus mealybug and assessment of toxicity post-fumigation.

Materials and Methods

Fumigants: Vapormate^{TM} (Ethyl formate 16.6%) was supplied from BOC Australia, and ECO2FUME^{TM} (Phosphine 2%) was supplied from Cytec Industries Inc.

Insects and Pineapples: Citrus mealybug was reared at a laboratory condition at 25°C temperature with 16:8hr [L:D] photoperiod. Before the fumigation experiment began, citrus mealybug was inoculated inside cracks on the pineapple fruit surface. The mortality of eggs, nymphs and adults was assessed after storage in an incubator for 72 hours at 25±2°C. For assessment of phytotoxicy, pineapples fumigated were stored at 8°C storehouse for 2 weeks where the index (0-5 scales) of phytotoxicity was measured.

PH_3 gas application (Dole Korea)

Commercial scale PH_3 fumigation on imported pineapples was performed in a metal fumigation chamber (203m^3, 15% f.r. w/v of fruits) located on the premises of Dole Korea. 2g/m^3 of PH_3 gas was injected through the stainless gas line into the chamber and fumigated for 24hr at 8°C. The concentration of PH_3 gas was monitored using a Certiph3os^{TM} phosphine monitor. After 24 hr fumigation, ventilation was performed with a 480m^3/min scale exhaust fan. During the ventilation, the concentration of PH_3 gas in and outside of fumigation chamber and inside of pineapple box was measured to access the re-entry time for workers.

EF mixed with PH_3 gas application (DelMonte Korea)

Commercial scale EF mixed with PH_3 gas fumigation was applied to imported pineapple. The process was done in a PVC-tarpaulin tent(168m^3, 15% f.r. w/v of

fruits) in DelMonte Fresh Produce Korea Company. 25g/m^3 of EF with 1g/m^3 of PH_3 gas were simultaneously applied through the vaporizer into the tent and then fumigated for 4hr at 8°C. To analyze the EF and PH_3 concentration, gas samples were collected in a Tedlar's gas sampling bag(SKC Inc.) and then analyzed with gas chromatography equipped FID and NPD. After 4 hr fumigation, ventilation was performed with two 147m^3/min scale exhaust fans. During the ventilation, the concentration of fumigant gas in and outside of the fumigation chamber and inside of pineapple box was monitored to access the re-enter time for workers.

Results:
The efficacy of PH_3 gas at controlling citrus mealybug and its phytotoxicity on pineapples is shown in Table 1. At the concentration x time (*Ct*) product of PH_3 gas of 40.8g·h/m^3, all stages of citrus mealybug were completely controlled and no phytotoxic effect was evident on pineapples. After 40 min of ventilation, there was less than 0.3 ppm PH_3 in all three locations tested, below the threshold limit value(TLV) (Fig. 1).
The efficacy on three different stages of citrus mealybug and phytotoxicity of pineapples fumigated with EF plus PH_3 gas in commercial scale fumigation is shown in Table 2. The Ct product of EF and PH_3 gas was 36.0 and 2.6 g·h/m^3, respectively. All stages of citrus mealybug were completely controlled with no phytotoxic damage (index 0) on pineapple fruits. To allow worker re-enter to the fumigation site, total ventilation time for TLV of PH_3(0.3ppm) was expected more than 90 minutes to all three monitored sites (Fig. 2). Regarding assessment of TLV of EF (100ppm), ventilation time estimated was less than 30 minute.

Conclusions: In these commercial trials, we've verified two MB alternative fumigants; PH_3 gas fumigation and an EF-PH_3 mixture, on imported pineapple. In commercial-scale applications, both fumigations showed the commercial acceptance in terms of efficacy on the target pest, lack of phytotoxicity on pineapple fruits, and more rapid ventilation time than methyl bromide, important for worker safety.
PH_3 gas fumigation takes longer (24hr) than does EF mixed with PH_3 (4hr), which is beneficial when rapid turnaround is important, but the mixture compounds is more expensive than PH_3 gas alone. A well designed fumigation system equipped with fitted more efficient exhaust system would reduce the ventilation time for re-entry.

Table 1. Efficacy of citrus mealybug control, and phytotoxicity to pineapples in commercial scale PH_3 gas fumigation

Trt. (8±1 ℃)				Efficacy(%)			Phytotox.
Fumigant	Dose (g/m^3)	Time (h)	CT ($g\ h/m^3$)	Citrus mealybug			Pineapple
				Eggs	Nymphs	Adults	Index[a] (0-5)
Phosphine	2	24	40.8	100% (0/1140)	100% (0/790)	100% (0/146)	0

[a] index 0: no phytotoxic effect, 1: very slight, 2: slight, 3: moderate, 4: serious, 5: very serious

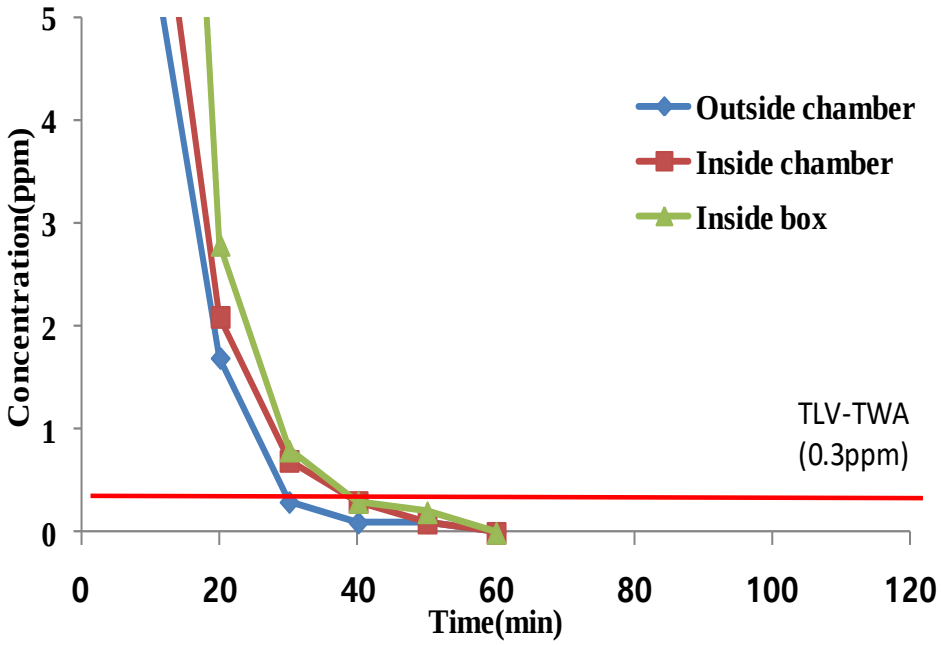

Fig 1. Concentration of desorbed PH_3 gas by ventilation time at three different locations in metal fumigation chamber ($203m^3$)

Table 2. Efficacy on citrus mealybug control, and phytotoxicity to pineapples in commercial scale EF mixed with PH_3 gas fumigation

Trt. (8±1 ℃)				Efficacy(%)			Phytotox.
Fumigant	Dose (g/m^3)	Time (h)	CT ($g\ h/m^3$)	Citrus Mealybug			Pineapple
				Eggs	Nymphs	Adults	Index[a] (0-5)
Ethyl formate	25	4	36.0	100% (0/850)	100% (0/340)	100% (0/89)	0
Phosphine	1						

[a] index 0: no phytotoxic effect, 1: very slight, 2: slight, 3: moderate, 4: serious, 5: very serious

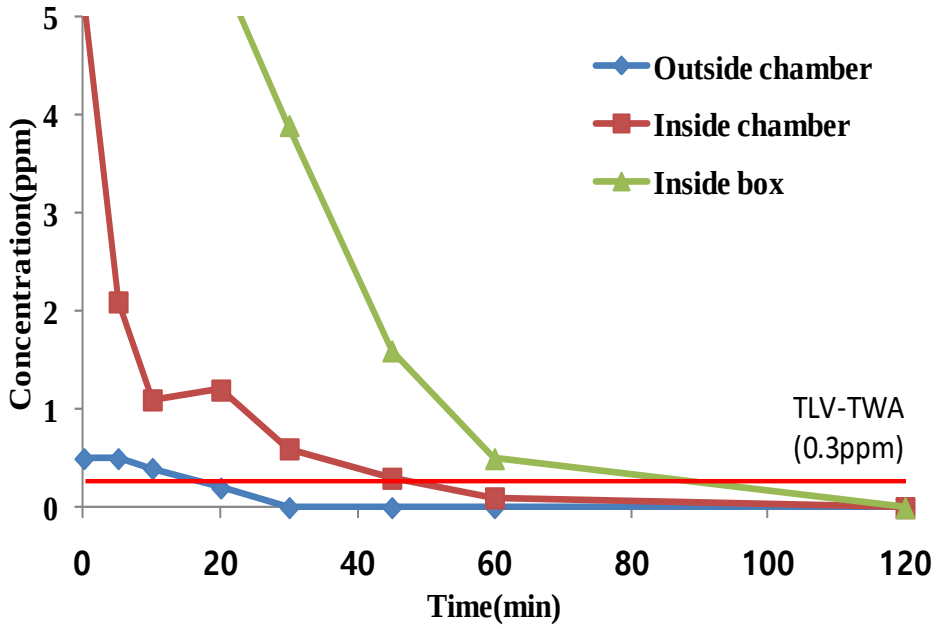

Fig 2. Concentration of desorbed PH_3 gas by ventilation time at 3 different locations in a PVC-Tarpaulin tent ($168m^3$)