Ethyl formate application trials for in-transit fumigation of shipping containers

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Two ethyl formate/nitrogen in-transit trials have been conducted on containerized goods in shipping containers under winter and summer temperature ranges to provide a representative dataset of year round temperature conditions in Western Australia. The winter trial was conducted in September 2017 and the summer trial in December 2017. Overall, the trials demonstrated that ethyl formate/nitrogen fumigation exposure periods could be successfully completed in-transit, with zero risk to the public or workers from exposure to ethyl formate throughout the two-day journey. The results show that more than half of the applied ethyl formate/nitrogen concentration was maintained over the six-hour exposure period. This is consistent with the fumigant decay of a shipping container undergoing a stationary fumigation exposure period. These results also show that the environmental influence on a moving container under fumigation was negligible in reducing the efficacy of the treatment. Environmental gas concentration measurements taken throughout the journey indicated nil presence of ethyl formate in the immediate surroundings of the containers up to 15 metres downwind, as well as inside the cab of the truck. These results further suggest that there would be zero risk to workers if the containers were vented at the end of the two-day journey. Continuing the in-transit period would eliminate the requirement for ventilation screens to be installed whilst undergoing ventilation.

Safe and cost-effective method for application of liquid ethyl formate (Fumate™) as a methyl bromide alternative for perishable commodities

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Abstract

The cylinderized liquid ethyl formate (EF) formulated with CO_2 is one of the great potential fumigants to replace methyl bromide (MeBr) for fresh fruit. However, it is too expensive to adapt commercial practices, and also involves work place safety issue including handling of heavy cylinders as well as restrict emission of CO_2, particularly for use in large scale commercial fumigationw. Therefore, it is urgently needed to develop environmental friendly, safe for workers and cost-effective alternative method for application of liquid ethyl formate as a MeBr alternative for perishable commodities. Recently, the environmentally friendly, cost-effective and practically safe use of liquid EF (Fumate™, registered name) with nitrogen gas has been developed and commercialized in Republic of Korea and Australia. The new technology for application of liquid EF is 100 times safer than MeBr in terms of threshold values (EF, TLV = 100 ppm). Ethyl formate is known as food additive and naturally occurred substances as well as a non-ozone depletion chemical. In this report, we demonstrate the liquid EF application technology that offers a clean environment (no ozone depletions and CO_2 emissions), safe to fumigators and related workers and practically cost-effective technology to fumigation industry.

Keywords: Quarantine fumigation, Ethyl formate, Fumate™, perishable commodities.

1. Introduction

Methyl bromide (MeBr) had being planned for phasing out and recommended to reduce its usage by the International Plant Protection Convention (IPPC) since the 1990s. Therefore, from point of view of protecting ozone policy and conducting safe fumigation by operators and related workers, MeBr must be urgently replaced. Intially ethyl formate (EF) with carbon dioxide formulation in cylinder offered replacment of MeBr for fumigation of fresh fruit (Ryan et al., 2013). However, cyliderized EF formulation has some hudles for its broad commerical use. This is because it is too expensive to use as fumigant, especially at a high dose rate (70g m^{-3}), such as fumigation of citrus. It also frequently involved worker safety issue for handling of heavy cylinders. In order to sucessfully achieve cost-effective and practically safe use of liquid EF with nitrogen gas, long-term and continousely cooperative research and developement has been conducted between Murdoch University and Animal and Plant Quarantine Agency (APQA). Here, we report various commerical demonstration trials with new liquid EF application technology on perishable commodities such as orange, banana, lemon and grapefruit and vertify the current quarntine protocols in Korea.

2. Materials and Methods

2.1 Fumigants and fumigation

Ethyl formate (Fumate™, 99%) was supplied from Safefume Inc. Korea. Ethyl formate was vaporized with heated nitrogen gas through the nitrogen heater, which fitted in vaporizer (SFM-1) and discharged into the fumigation chamber.

2-2. Commercial scale fumigation tests

Commercial scale trials were performed at Busan port, South Korea. A 40ft shipping container and PVC-tarpaulin fumigation chambers (81-424 m^3) were used. Ethyl formate was applied with SFM-1 (EF vaporizer) at dose rate of 70 g m^{-3} for citrus (orange, lemon and grapefruit) and 35 g m^{-3} for banana; exposed at > 5°C (citrus) and >13°C (bananas) for 4 hours. After 4 hours of fumigation, the container and chamber were opened and ventilated for > 1 hours. The phytotoxicity of ethyl formate on commodity was investigated after 2 weeks of fumigation held at room temperature conditions.

2-3.Measurement of fumigant concentration

Ethyl formate was drawn with an electric pump at timed interval and stored in Tedlar's gas sampling bags (1L, SKC Inc.). The concentration of EF was measured by a portable EF analyzer (iBRD MX, Industrial Scientific) and some random gas samples were analysed with a GC-FID (Agilent Technology 7890N) at laboratory to compare accuracy of portable EF analyzer.

3. Results and Discussion

The cumulative Ct products of ethyl formate in inside and outside bag of banana were calculated at the range of 26.1 to 42.0 g h m^{-3} and 35.5 to 78.8 g h m^{-3}, respectivly. In case of citrus fumigation, the Ct products were 102.6 to 133.7 g h m^{-3}. However, the same commodites even treated with same calulated dose of fumigant, the Ct products can be significantly different which depend on the conditons of loading ratio, types of application facilities (period of application) etc. The commercial trials with liquid EF applied with SFM-1 (EF vaporizer) have obtained different Ct products at different treatment conditions. However, liquid EF fumigation with nitrogen has met the current quarantine protocols on fruit fumigaiton in Korea. The efficacy of fumigation with EF achieved complete control of target pests such as citrus mealy bugs (*Planococcus citri*), California red scale (*Aonidiella aurantii*), Foller'rose weevil (Naupactus godmanni) etc. on imported Citrus and *Aspidiotus excisus* on banana. The results from phytotoxic acessment demonstrated privously by Kim et al., (2017) and Yang et al., (2016, 2017) and indicate that this new technology to apply liquid EF suits

the commercial fumigation practice and regulatory point of view for replacement of MeBr and conducting of good fumigation practice to ensure worker and envorimental safety.

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Table 1. Cumulative CTP (Concentation X Time product, g h m^{-3}) of 4 hr Ethyl formate fumigation on imported fruits depending on different conditions in commercial trials

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