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CONTROL OF *BREVIPALPUS CHILENSIS* WITH PHOSPHINE ON FRESH FRUITS UNDER COLD STORAGE FUMIGATIONS

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ABSTRACT

The fruit export industry in the world faces a significant problem with the phase out of methyl bromide, the most important fumigant for the control of quarantine pests on export fresh fruits. In 2005, Fosfoquim developed in Chile a method where pure cylindered phosphine, VAPORPH$_3$OS®, is applied through the Horn Diluphos System™, for the control of pests on fresh fruits under cold storage conditions. The Horn Diluphos System™ is a phosphine and air blending equipment developed in the year 2001 in Chile that allows the dispensing of pure cylindered phosphine mixed with air at a concentration below the point of ignition. Since then this method has been used commercially in a large scale in Chile for the control of different pests like mealy bugs, thrips, moths and scales. Normal fumigation conditions are cold storage temperature (normally 0ºC), 24 – 48 h exposure time and 1,000 to 2,000 ppm phosphine concentration. In Chile only, almost 12,000 fumigations have been made applying pure cylindered phosphine VAPORPH$_3$OS to fresh fruits.

Some countries have specific pests that limit their export to other countries. This is the case of Chile with the false Chilean Mite. Although good control is achieved with phosphine under the normal fumigation conditions at 0ºC, 24 - 48 h and 1,000-2,000 ppm, the pest cannot be controlled 100 % for all stages. After extended research, new conditions were found to effectively control the false Chilean mite using pure cylinderized phosphine blended with air. The tests for *Brevipalpus chilensis* were carried out on apples at a temperature of 0ºC, a concentration of 300 ppm and 10 days exposure time. The tests showed that adults and nymph stages could be controlled at 100 %, while the control showed a survival rate of 87.9 %. Tests were made with 100 individuals with 3 replicates.

Key words: phosphine, cylindered phosphine, Horn Diluphos System, HDS, VAPORPH$_3$OS®, fumigation, fresh fruit fumigation, vegetable fumigation, cold storage fumigation, postharvest phosphine fumigation, mites, quarantine fumigation.

INTRODUCTION

Phosphine gas, has been used for over 75 years as an insecticide, and it is presently the most accepted fumigant for stored products, like grain, nuts, dried fruits and others

Phosphine has the great ecological advantage that its application in pure form from cylinders does not leave harmful residues in the environment or in treated products.

Nevertheless, because phosphine forms explosive and self flammable mixtures with air at concentrations over 18,000-ppm, it had not been possible to apply phosphine in its pure

state by means of direct dilution with air, even though this would be the best way to apply the gas.

Phosphine has been always obtained by on site hydrolysis of a metal phosphide compound, like aluminum phosphide or magnesium phosphide.

In the year 2001, a new a method was developed to blend directly pure phosphine with air. Since then, this new tool has been used now for some years in many countries for different applications such as:

- Fumigation of grain in silo bins, flat storages and bunker storages
- Fumigation of flour mills, minimizing risk of corrosion
- Sea containers
- Fumigations chambers

With this new tool at hand, where pure phosphine could be applied without generating the byproducts ammonia and carbon dioxide, phosphine started to be used in Chile for the control of pests in fresh fruits and vegetables in the year 2005.

For several years, before this new treatment was developed, phosphine had been investigated as a fumigant for the treatment of fresh fruits and vegetables. The research has shown good results as for mortality of insects. However, acceptable results were not obtained in reference to the quality of treated fruit, which had always suffered damage. This damage has been caused by two reasons mainly: presence of ammonia and relatively high fumigation temperature, over 15°C, to which the tests have been exposed. At high temperature the metabolic activity of the fresh fruits and vegetables is still important and, as phosphine acts through the blocking of the metabolic activity, phosphine also affects the quality of the fruits at high temperature.

Aluminum phosphide or magnesium phosphide based products have the great disadvantage that, if they are used at low temperature, they produce phosphine very slowly and that they always produce ammonia as a by-product and ammonia is known to be very phytotoxic. For that reason, damage to the fruit is always expected when using metal phosphides.

But on the other hand, because of the pyrophoric characteristics of the product, until the direct blending of pure phosphine with air was developed in the year 2001, it was not possible to apply pure phosphine for fumigations.

When phosphine started to be used in Chile for fresh commodities, like fruits and vegetables, it was found that it is possible to carry out fresh fruit fumigation with pure phosphine free from ammonia, at low temperatures and with high gas concentrations, without affecting the quality of the fruit and eliminating most of the pests hosted on fresh fruits and vegetables.

The gas is normally applied in fumigation chambers, cooling chambers or controlled atmosphere chambers.

It was determined that this can be done successfully if the fumigation is carried out at a temperature between –1.5 and 6ºC with a concentration of pure phosphine free from ammonia, between 1000 and 1500 ppm in a sealed enclosure, with an exposure time between 24 and 72 h.

It was discovered that when lowering the temperature, it is possible to carry out the fumigation with a very high concentration of phosphine with no damage to the fruit, since at that temperature, the metabolic activity of fruit is slowed down. This high concentration compensates the low activity of the insects at low temperatures, controlling the pests.

Some small off-taste in fumigated fruit was observed following the fumigation, but this disappeared after 5 or 6 days of storage at low temperatures.

The best way to do the treatment with phosphine is to fumigate the fruit directly in the cooling chambers, where the fruit is stored after the selection process, and leaving the cooling system working during the whole fumigation period.

The fruit is preferably treated at the optimum cold storage temperature of each species. For example, for apples, grapes, kiwis and berries, pears, nectarines, peaches, etc. it is preferable the treatment with temperatures from –1.5 to 2°C. Other fruits like avocados, citrus and mangoes are preferably to be treated to their corresponding cold storage temperature.

So far, the treatment with high dosages of methyl bromide (30-60 g m^{-3}) was the most used and effective fumigation method for fresh fruits, which, although quick and efficient, has a series of disadvantages, such as the known ozone depletion, phytotoxicity, residues and worker exposure.

The use of pure phosphine has as main advantages, compared to methyl bromide, that it does not leave bromine residues in the fruit after treatment and that after liberated into the atmosphere, phosphine is oxidized into phosphates by the action of sunlight. It has also great advantages for workers, as the fumigation operation could be done from the outside of the facility, avoiding workers exposure to confined spaces, and it is not required to manipulate directly the fumigant as the fumigation equipment is a closed system

It has been demonstrated that it is possible to control the main pests of the fruit, such as the mealybugs, *Pseudococcus spp*; apple moth, *Cydia pomonella*; *Eulia* spp,, *Proeulia* spp.; fruit tree weevil, *Naupactus xanthographus*; Mediterranean fruit fly, *Ceratitis capitata*; fruit flies, *Bactrocera* spp., *Anastrepha* spp.; and *Thrips* spp. (Horn 2006).

Only in Chile, over 12,000 fumigations have been made applying pure cylindered phosphine VAPORPH$_3$OS® to fresh fruits

But, even though, most of the pests on fresh fruits could be controlled in an effective way, some pests had not been effectively controlled with the current fumigation protocol. The pests that had not been possible to control were two important quarantine pests for the Chilean export markets. One is the false Chilean mite, *Brevipalpus chilensis* (Baker), and the other pest is the European grapevine moth, *Lobesia botrana* (Denis and Schiffermüller).

Recently the conditions were found at which also these two pests can be controlled effectively.

MATERIALS AND METHOD

The treatments where performed in 28.3 L fumigation chambers on apples that were conditioned for 24 h between 0 and 10ºC. The apples were infested with *B. chilensis* that were grown on *Ligustrum sinensis* without having being treated with other chemicals.

Fumigation conditions were:

Phosphine concentration: 300 ppm, Control 0 ppm.
Fumigation temperature: 0ºC to 1ºC.
Exposure time: 10 days
Fruit species: Apple
Filling factor: 50% v/v

Two treatments with three replicates were made with 100-300 individuals in mobile stages for each replicate.

Pure phosphine blended with nitrogen was injected into the chamber to obtain a concentration of about 650 to 800 ppm of phosphine that would allow achieve 300 ppm phosphine at the end of the fumigation.

Phosphine concentrations were monitored on a daily basis using 0-2,000 ppm colorimetrical tubes. According to concentration readings, top ups were made to maintain the concentration according to the fumigation schedule. Four top ups were required to keep the concentrations within the schedule. Mortality was evaluated 5 days after aeration through visual inspection under stereoscopic microscope

Table 1. Phosphine concentration durinsg fumigation

Exposure time	Phosphine concentration in ppm			Top ups
	Replicate 1	Replicate 2	Replicate 3	
2 min	700	650	650	
24 h	300	250	200	
24 h after topup	800	750	800	1st
96 h	200	150	150	
96 h after topup	850	800	900	2nd
120 h	500	550	400	
144 h	50	50	50	
144h after topup	700	700	750	3rd
168 h	450	400	400	
168h after topup	600	550	600	4th
240 h	300	200	250	

Table 2. *Brevipalpus chilensis* mortality 5 days after fumigation with phosphine at 300 ppm for 240 h

Treatment	Replicate	Mobile stages treated	Mortality 5 days after aeration		
			Nº of live individuals	Nº of dead Individuals	% of mortality
Phosphine at low concentration for 10 days at temperature of 1ºC.	R1	250	0	250	100
	R2	223	0	223	100
	R3	301	0	301	100
	Average		0	258	100
	Std. Deviation		0	35,4	0
	Std. Error		0	20,5	0
Control without fumigation at temperature of 1ºC	R1	129	119	10	7,8
	R2	442	384	58	13,1
	R3	405	343	62	15,3
	Average		282	43,3	12,1
	Std. Deviation		127,6	25,9	3,5
	Std. Error		73,7	14,9	2

RESULTS AND DISCUSSION

It could be demonstrated that pure cylindered phosphine is able to control 100% of mobile stages of *B. chilensis* in fresh fruits when exposed for 10 days to concentrations averaging 457.5 ppm with average temperatures of 1ºC.

Mortality of control was 12.2% which corresponds to the natural mortality of the tested population.

The proposed treatment is an effective tool for the control of mites on fresh fruits, especially considering those fruits that are stored for longer periods of time, and where the same cooling infrastructure can be used as fumigation facility such as table grapes, kiwifruit, apples, and others.

Similar results as with *B. chilensis* have also been obtained with other quarantine pests like the grapevine moth, *L. botrana* .

There are a series of advantages when fumigating fresh fruit with pure cylindered phosphine using the HORN DILUPHOS SYSTEM^{TM}:

- No changes in taste, smell, texture, color or shelf life of the fruit after 6 days of aeration, if fumigation has been conducted at low temperature.
- It is possible to fumigate at low temperature with the cooling system running.
- It is not necessary to warm up the fruits prior to fumigation.
- There are no residues left after fumigation.
- Pure cylindered phosphine does not produce ammonia and it is, therefore, not phytotoxic.
- The fumigation can be performed in the same cooling chambers where the fruit is stored.
- Hydrogen phosphide is rapidly deactivated by the action of sunlight once released to the atmosphere.
- Phosphine does not damage to the ozone layer and it is not a gas with greenhouse effects.

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