Therefore, fumigations are an effective option in manufacturing, storage and shipment. Since the International Standard for Phytosanitary Measures No. 15 (ISPM 15) is approved, container fumigations against quarantine pest have become important and customary in international trade.

We investigated several subjects related to fumigation such as occupational safety, modification of flavor profiles in fumigated crops and the development of resistance against fumigants.

Fumigation of goods for protection against pests is common practice in the context of global trading. One of the most commonly used fumigants for this purpose is phosphine (PH3). Apples are fumigated prior to export to control eggs of pest insects like the codling moth (*Cydia pomonella*). In this study we addressed the question whether phosphine fumigation affects the aroma profile of apples (*Malus domestica* 'Royal Gala'). For this purpose, a headspace solid-phase micro-extraction (HS-SPME) technique was developed and coupled to subsequent gas chromatography-mass spectrometry (GC-MS).

Previously we looked into the desorption behavior of phosphine after the fumigation of apples and sunflower seeds. Furthermore, the effects of fumigation on the overall volatile profiles were studied. Alterations of the volatile profiles were observed for apples and sunflower seeds.

A second question addressed concerns the adsorption and desorption behavior of phosphine from apples and sunflower seeds under different conditions as well as the chemical residues. The impact of the initial fumigation concentration and of the storage temperature was analyzed. The phosphine concentration was thereby monitored using GC-MS instrumentation.

Dates fumigation with phosphine

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Abstract

Stored dates are usually infested by sap beetles and moths. For years, the common practice for dates disinfestation was fumigation with methyl bromide (MB). After MB phase-out, heat treatment and modified atmosphere are used. However, there are several limitations of these methods. In search for alternatives for dates disinfestation, fumigation by phosphine was evaluated.

Commercial fumigations of Medjool dates variety using phosphine were conducted in a standard 20 ft. shipping container. Two formulations of phosphine were used: Magtoxin® Plates 56% (Detia Freyberg GmbH, Germany), and Phostoxin® Tablets 56% (Detia Freyberg GmbH, Germany). The phosphine dosage range was 1-4 g/m^3. The exposure time range was 24-72 hrs. Several fumigations were carried out by an innovative phosphine generator model OMT 501 developed by Universal Probes. Most fumigations carried out demonstrated total dates disinfestation. The application of Magtoxin plates, especially using the OMT 501 demonstrates significant advantages versus Phostoxin tablets; the advantages were in quicker gas development, and achieving much higher maximum and pre-ventilation phosphine concentration levels. Upon fumigation using the OMT 501, plates are easily collected and disposed, no residual dust left on the dates, which avoided their contamination. No phosphine residues were found in the fumigated dates, neither changes in organoleptic properties were noted. Phosphine fumigation using the phosphine generator model OMT 501 provides safer, quicker, more efficient dates disinfestation.

Keywords: fumigation, phosphine, dates

Introduction

Stored dates are usually infested by sap beetles and moths. For years, the common practice for dates disinfestation was fumigation with methyl bromide (MB). After MB phase-out, heat treatment and modified atmosphere are in use (Navarro, 2006; Navarro and Navarro, 2015; Rafaeli et al., 2006). However, there are several limitations of these methods. Today, phosphine is the main fumigant for postharvest treatment in stored products, such as grain and dry food. To improve the phosphine

fumigation some innovative technologies were suggested (Kostyukovsky and Shaaya, 2012; Kostyukovsky et al., 2010; 2013). In search for alternatives for dates disinfestation, fumigation by phosphine was evaluated.

Materials and Methods

Two standard 20 Ft shipping container were used for the fumigations. One container was used as it is without special sealing. The other one was sealed especially for the treatments.

Two formulations of phosphine were used: Magtoxin Plates, 56% (Detia-Degesh, Germany), or Phostoxin Tablets, 55% (Detia-Degesch, Germany). The range of phosphine concentrations used was 1-4 g/m^3. The range of exposure time was 24-72 hrs (1-3 days). The treatments were done with or without the phosphine generator model OMT 501 (Universal Probes, Israel). The list with all fumigation treatments is shown in table 1.

Tab. 1 Fumigation treatments

Trial #	Phosphine formulation	OMT 501	Dosage g/m^3	Quantity	Exposure time
1	**Magtoxin Plates**	V	4	4 Plates	1 day
2	**Magtoxin Plates**	V	2	2 Plates	1 day
3	**Magtoxin Plates**	V	2	2 Plates	2 days
4	**Magtoxin Plates**	-	2	2 Plates	3 days
5	**Phostoxin Tablets**	-	2	66 Tablets	5 days
6	**Phostoxin Tablets**	-	1	33 Tablets	1 day
7	**Phostoxin Tablets**	-	2	66 Tablets	1 day
8	**Magtoxin Plates**	-	2	2 Plates	1 day
9	**Magtoxin Plates**	V	1	1 Plates	1 day
10	**Phostoxin Tablets**	-	3	99 Tablets	2 days

Before starting the fumigation treatments, a sample of non-treated dates of 1 kg each, was taken as a control for efficacy evaluation. After the fumigation treatments, three dates samples 0.5 kg each were taken from different locations in the container for efficacy evaluation and phosphine residues analysis.

During the entire fumigation period, the phosphine concentrations levels inside the containers were monitored every two hours.

Results

The results showed that concentrations of phosphine in the non-special-sealed containers were very low (table 2, trials 4, 5). In contrast, in the container that passed special sealing before fumigation, a much higher concentration of phosphine were recorded (table 2, trials 1-3, 6-10). The highest concentrations were reached using Magtoxin plates, 4 g/m3 X 24 hrs with the phosphine generator model OMT 501 (table 2, trial 1). However, also at lower dosage of 2 g/m3 X 24 hrs and 2 g/m3 X 48 hrs using the OMT 501, high phosphine concentrations were achieved (table 2, trials 2, 3). The exposure time of 48 hrs does not have a significant advantage compared with 24 hrs (trials 2, 3). When the Magtoxin plates were used without the OMT 501, the highest concentrations were recorded much later compared with the trials with the OMT 501 (Table 2, trials 2, 9). Using Phostoxin tablets, only at the dosage of 3 g/m3 X 48 hrs the concentrations of phosphine were satisfactory (table 2, trial 10), but were reached much later compared with the Magtoxin plates and especially when using the OMT 501.

Tab. 2 The Phosphine concentrations in the field trials

Trial #	Phosphine formulation	OMT 501	Dosage g/m^3	Exposure time h	Concentration ppm after 4 h	max	final	Time (h) for max. conc.
1	**Magtoxin Plates**	V	4	24	1000	2100	900	8
2	**Magtoxin Plates**	V	2	24	650	1200	500	9
3	**Magtoxin Plates**	V	2	48	600	1050	350	10
4*	**Magtoxin Plates**	-	2	48	20	160	16	24
5*	**Phostoxin Tablets**	-	2	72	21	240	0	12

6	**Phostoxin Tablets**	-	1	24	60	300	300	24
7	**Phostoxin Tablets**	-	2	24	60	580	460	21
8	**Magtoxin Plates**	-	2	24	175	900	750	21
9	**Magtoxin Plates**	V	1	24	270	400	280	10
10	**Phostoxin Tablets**	-	3	48	13	770	730	35

* - non-special-sealed containers

The range of the dates infestation in the control was 3% to 30%. The dates were infested with alive adults of sap beetles (Coleoptera: Nitidulidae) and the larva of moths. Post fumigations no live insects were found. The dates infestation by dead insects in Magtoxin plates using the OMT 501 was 0-1%, in plates without the OMT 501 2%, in the trials with the tablets 2-18% (table 3).

Tab. 3 The efficacy of Phosphine fumigation in dates disinfestation in the field trials

Trial #	Phosphine formulation	OMT 501	Dosage g/m³	Exposure time h	Date infestation % control		treatment	
					alive	dead	alive	dead
1	**Magtoxin Plates**	V	4	24	6	0	0	0
2	**Magtoxin Plates**	V	2	24	9	0	0	3
3	**Magtoxin Plates**	V	2	48	6	0	0	2
6	**Phostoxin Tablets**	-	1	24	3	0	0	2
7	**Phostoxin Tablets**	-	2	24	6	0	0	18
8	**Magtoxin Plates**	-	2	24	12	0	0	2
9	**Magtoxin Plates**	V	1	24	22	7	0	5
10	**Phostoxin Tablets**	-	3	48	3	3	0	8

No phosphine residues were found in any of the fumigated dates.

Discussion

The best results were achieved in the trials with Magtoxin plates using the OMT 501. The plates have significant advantages versus tablets by achieving the highest levels of phosphine concentrations much faster, resulting in dates disinfestation. In addition, plates have obvious safety advantages versus tablets. Standard (common) containers without special sealing are not suitable for fumigation.

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Determination of phosphine concentration for *Cryptolestes ferrugineus* (S.) control in wheat in Sonora, Mexico

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