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THE APPLICABILITY OF CONTROLLED ATMOSPHERES AS AN ALTERNATIVE TO METHYL BROMIDE FUMIGATION OF DRIED FRUITS IN TURKEY

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ABSTRACT

Dried fruits are among the traditional agricultural products of Turkey which leads the field both in terms of quality and international trade. Approximately 250.000 tons of dried raisins and 50.000 tons of dried figs are exported from Turkey annually,, which represents some 30-35% and 50-55% of the total world trade, respectively.

The purpose of this study was to evaluate the effectiveness of high CO_2 applications in flexible PVC envelopes (Grainpro Cocoons) against dried fruit pests under field conditions as an alternative to MeBr. The CO_2 applications were performed in units of 36 m^3 capacity over 3-5 days exposure. The test insects contained all life stages of different ages of *Ephestia cautella*, *Plodia interpunctella*, *Oryzaephilus surinamensis*, *Carpophilus hemipterus* and the mite *Carpoglyphus lactis*. Temperature, r.h. and CO_2 and O_2 levels were continuously monitored during treatment.

The results showed that oxygen concentration in the envelopes decreased below 1% and CO_2 concentrations reached above 95%. Test insects were completely killed after 5 days of exposure. The cost of CO_2 application is similar to that of MeBr, namely: approximately US$ 1,7-3.5/ton dried fruit. This study indicates that dried fruits can effectively be disinfested with high CO_2 applications in flexible units without the use of MeBr.

INTRODUCTION

Turkey is the leading country in the world trade of dried fruits and edible nuts. In this category of agricultural products, sultanas, dried apricots, dried figs, hazelnuts, and pistachios are important exports. Annual dried fruit production of Turkey is ca. 350,000 tons of which 250,000 tons are sultanas and 50,000 tons are dried figs.

Dried figs in Turkey are infested by numerous pest species. Whereas *Ephestia cautella* (Walker), *Plodia interpunctella* (Hübner), and *Carpophilus hemipterus*

(Linnaeus) infest the fruits during the growing period in the orchards, *Oryzaephilus surinamensis* (Linnaeus) and *Carpoglyphus lactis* (Linnaeus) infestations occur in the processing plants after harvest (Ozer *et al.*, 1989; Anonymous, 1995).

Turkey as a signatory country of the Montreal Protocol has put a methyl bromide (MeBr) phase-out program into action that calls for the use of MeBr in dried fruit sector to be banned in 2004. However the Turkish dried fruit production sector is highly dependent on MeBr, and dried figs are the most vulnerable products of the MeBr ban. Hence, environmentally acceptable, user-friendly, cost effective and efficient alternatives to MeBr are the most urgent needs for the dried fig sector in Turkey.

Modified atmosphere (MA) applications have been the subject of numerous studies that have revealed them to be efficient against arthropod pests of dried fruits and as promising candidates to replace MeBr (Soderstrom *et al.*, 1984; Soderstrom *et al.* 1986; Navarro, *et al.*, 1993; Donahaye, *et al.*, 1994; Tarr *et al.* 1994; Donahaye *et al.*, 1998; Navarro, *et al.*, 1998*a*; Navarro *et al.*,1998*b*; Navarro, *et al.*, 2000). Recently, Navarro *et al.* (2002) referred to gas tight plastic enclosures for use in small-scale MA applications, particularly for high-value crops such as cocoa, coffee, and spices.

Thus, the objective of this study was to investigate the applicability of MA treatments in flexible gas tight envelopes to obtain total mortality of dried fruit pests under field conditions.

MATERIALS AND METHODS

MA application

Flexible PVC storage units (Cocoons from GrainPro Inc, USA) of 36 m^3 in volume were used. Approximately 15 tons of dried figs at 23% m.c. were loaded into the cocoons in perforated plastic boxes of 25-30 kg capacity. Test insects in small chambers were positioned at different levels of the stack before sealing. Carbon dioxide from steel cylinders was flushed in liquid phase into the cocoons. After the desired gas concentrations were reached, gas-in and gas-out taps were closed tightly (Fig. 1). Exposure periods were 3-5 days.

Monitoring equipment

CO_2 and O_2 concentrations at different levels in the cocoons were recorded daily using an analyser equipped with a thermal conductivity detector (Gow Mac CO_2 analyser Model 20-600), and an electrochemical detector (David Bishop Inst. O_2 analyser Model OxyCheck 2) for the entire exposure periods. The cocoons were also equipped with temperature and relative humidity (r.h.) loggers (Onset Co., model: Hobo® H8 Pro Series) (Fig. 1).

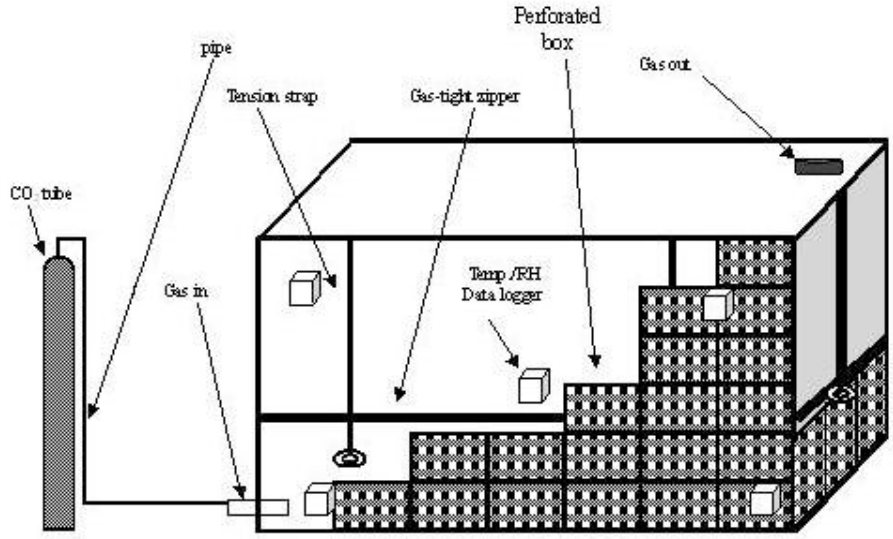

Figure 1. A schematic diagram of the cocoon showing experimental design

Test insects and mites

The test insects and mites were placed in 100 ml perforated plastic containers containing food (*E. cautella, P. interpunctella, O. surinamensis*) or naturally infested dried figs (*C. hemipterus, C. lactis*) (Table 1). In each trial five groups of insects were placed in different locations inside the cocoon (Figure 1). After the exposures to CO_2, the test insects were removed from the cocoons and held in a c.t. room at 25ºC and 65% r.h. Mortality of the active stages was determined 14 days after the end of exposure, while egg and pupal mortalities were evaluated as failure to hatch 10 days after the end of each trial.

RESULTS AND DISCUSSION

After flushing, high levels of CO_2 at above 90% were reached and these CO_2 levels remained more or less stable throughout the trials. Figure 2, for example, shows O_2 and CO_2 levels recorded in the PVC envelope for 120 hours of exposure. Gas compositions inside the cocoons were quite similar after 72 and 96 hours of exposure. The measurements of oxygen and carbon dioxide gas concentrations over the trials clearly showed that the cocoons were gastight and thus suitable for disinfestation practices of dried fruits by means of high CO_2 in comparatively short exposure times. The temperature and r.h data were also stable during the trials (Table 2).

TABLE 1
Numbers and the ages of test species at the stages used for testing their mortality rates

Species	Stage	Age (d) *	Number per replicate
Ephestia cautella (1)	eggs	1-3	100
Plodia interpunctella (1)	mature larvae	18-20 (1)	100
	pupae	1-3	50
Oryzaephilus surinamensis (2)	adults	1-2 (1)	50
Carpophilus hemipterus	mixed	mixed	uncounted

* age for larvae from egg stage; adults from emergence

TABLE 2
Mortality records of test individuals over different exposure periods.

Species	Stage	Age (d) *	Mortality (%)		
			Exposure time (d)		
			3	4	5
Ephestia cautella (1)	eggs	1-3	100	100	100
	mature larvae	18-20 (1) 14-16 (2)	100	100	100
Plodia interpunctella (1)	pupae	1-3	100	100	100
Oryzaephilus surinamensis (2)	adults	1-2 (1) 7-14 (2)	100	100	100
Carpophylus hemipterus **	mixed	mixed	<100	<100	100
Carpoglyphus lactis **					

* age for larvae from egg stage; adults from emergence
** naturally infested figs were used

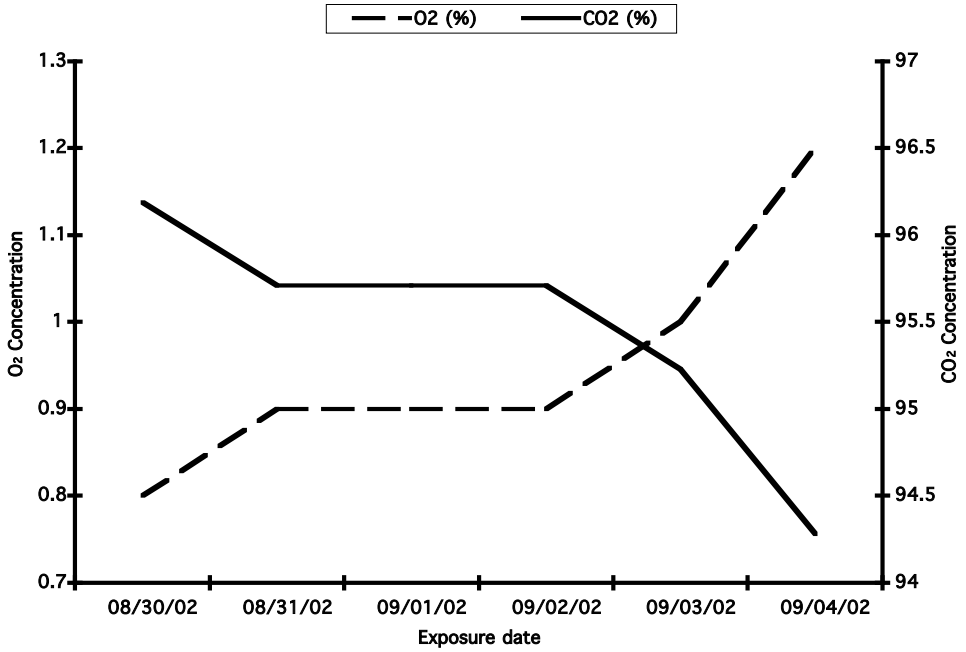

Figure 2. Carbon dioxide and oxygen levels measured inside the cocoon during 5 days of exposure

According to the mortality results shown in Table 2, all developmental stages of *E. cautella*, *P. interpunctella* and *O. surinamensis* were completely killed at high carbon dioxide (> 90%) atmospheres after 3 days of exposure. *C. hemipterus* and *C. lactis*, on the other hand, could only be killed after 5 days of exposure. Similar results were reported in previous studies by other researchers. Navarro *et al.* (1990) suggested that a complete mortality of most stored-product pests using high carbon dioxide would require an exposure to > 60% CO_2 for at least 11 days. Navarro *et al.* (2002), when testing various MAs in plastic enclosures reported that LT_{99} values for the most resistant stages of *E. cautella* (pupae) and *O. surinamensis* (eggs) at 35ºC and at 90% CO_2 were only 17 and 9 h, respectively. They also reported that under the same CO_2 concentration but at 30ºC, the LT_{99} for *O. surinamensis* (eggs) was 22 h. Hashem and Reichmuth (1994) reported that egg mortality of *Ephestia elutella* (Hubner) at 90% CO_2 at 25ºC was 100% for 3 days of exposure. Markze *et al.* (1970), who studied *P. interpunctella* pupae exposed to an atmosphere composed of 97.2% CO_2+0.8% O_2+2.0%N_2 at 27ºC and 61% r.h. reported that a complete failure of the emergence of pupae was obtained within 3 days. Navarro and Calderon (1974) found that in a MA atmosphere composed of 86% CO_2 + 10% 0_2 + 4% N_2 a complete mortality of *E. cautella* pupae was obtained in 4 days at 54% r.h. and 26ºC. Navarro *et al.* (1985)

found that complete mortality of the adult stage of *Acarus siro* (L.) in an atmosphere containing 2% O_2 with the remainder N_2 at 26ºC was reached after two days of exposure. *Carpophilus* species are important pests of dates grown in Israel (Navarro *et al.*, 2001). High CO_2 atmospheres of 60-80% carbon dioxide created in plastic chambers loaded with dates were found to be effective to prevent insect development and to preserve fruit quality over for 4,5 months of storage in Israel and were proposed for other dried fruits to control pests and maintain quality (Donahaye *et al.*,1998; Navarro *et al.*, 1998a; Navarro *et al.*,2001).

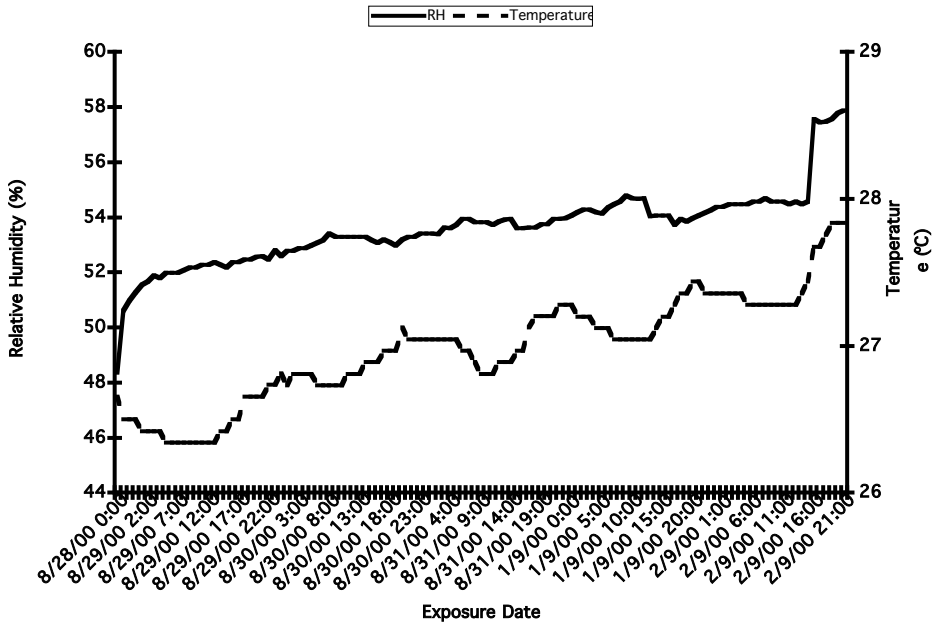

Figure 3. Temperature and relative humidity records inside the cocoon during 5 days of exposure

The cost of CO_2 application from steel cylinders in the trials can be comparable to that of MeBr and is around US$ 1,7-3.5/ton dried figs. In the case of gas supplied in bulk, the cost would be even lower.

In conclusion, the use of high carbon dioxide atmospheres to control pests of dried fruits in PVC enclosures in comparatively short exposure periods look extremely promising. It was possible to obtain a high level of CO_2 (> 90%) with an initial flushing of CO_2 in the liquid phase and to maintain it for at least 5 days without any additional CO_2 top-up. The cost of high CO_2 applications is comparable to that of MeBr. Though the time required to kill 100% of the pests varied between species, for all the pests tested, exposures for 120 hours were sufficient to ensure

complete kill. Thus, the use of high CO_2 atmospheres in PVC envelopes can effectively replace the current use of MeBr.

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