Aksoy U, Sen F, Meyvaci KB (2012) Effect of post-harvest carbon dioxide application on storage pests and fruit quality of dried figs. In: Navarro S, Banks HJ, Jayas DS, Bell CH, Noyes RT, Ferizli AG, Emekci M, Isikber AA, Alagusundaram K, [Eds.] Proc 9th. Int. Conf. on Controlled Atmosphere and Fumigation in Stored Products, Antalya, Turkey. 15 – 19 October 2012, ARBER Professional Congress Services, Turkey pp: 166-171

EFFECT OF POST-HARVEST CARBON DIOXIDE APPLICATION ON STORAGE PESTS AND FRUIT QUALITY OF DRIED FIGS

Uygun Aksoy[1*], Fatih Sen[1] and K. Betul Meyvaci[1]

[1]Ege University, Faculty of Agriculture, Department of Horticulture, 35100 Izmir, Turkey
*Corresponding author's e-mail: *uygun.aksoy@gmail.com*

ABSTRACT

In Turkey, methyl bromide (MB), a fumigant used widely in controlling storage pests of dried figs was banned by January 1, 2007 leading to continuous search for alternatives especially for the dried fruit sector. The present experiments were designed to test the effects of carbon dioxide (CO_2) at atmospheric pressure (94 % CO_2 for 7 days in gas-tight cubes) and under high pressure (2, 3 and 5 h at 20 bars and 98% CO_2) on major storage pests (*Ephestia cautella* and *Carpoglyphus lactis*) of dried figs. CO_2 concentrations, temperature (^oC) and relative humidity (%) values were monitored during treatments. Comparisons were made with control fruit treated with MB (60 $g.m^{-3}$ for 24 h). Dried fig quality was assessed after the treatments and after 2.5 months of storage at ambient conditions. All tested CO_2 treatments controlled both of the tested pest species and had no negative effect on dried fig quality. Among tested treatments, high pressure application of CO_2 required high investment cost however was effective even at very short exposure periods as 2 h. CO_2 application in gas-tight cubes was recommended as a low-cost alternative despite its longer exposure requirement. CO_2 fumigation is allowed in organic certification systems and thus can be recommended for organic dried figs and other fruit and nuts that have a high demand in the organic market.

Key words: *Ficus carica*, controlled atmosphere, *Ephestia cautella*, *Carpoglyphus lactis*, fruit quality

INTRODUCTION

For many decades, Turkey has been the major dried fig producer and trader known also for its supreme dried fruit quality. However, pests may create significant problems and damage fruits if not controlled before and during storage. Major storage pests of dried figs are reported as *Ephestia cautella* Walk., *Plodia interpunctella* Hbn. (Lepidoptera: Pyralidae), *Oryzaephilus surinamensis* L. (Coleoptera: Silvanidae), and *Carpophilus hemipterus* L. (Coleoptera: Nitidulidae) in decreasing order of importance for Turkey and Greece (Turanlı, 2003; Eliopoulos and Athanassiou, 2004) whereas *Carpophilus* spp. is the main pest in California (Smilanick, 1979). *Carpoglyphus lactis* (L.) (Acari: Carpoglyphidae) may also create significant problems in stored dried figs. The pest damage occurs by feeding and by contaminating through droppings, webbing and other residues. There are tolerance limits foreseen in the dried figs market standards for each quality class (Anonymous, 2006).

Methyl bromide was the unique fumigant for disinfestation of storage pests with its wide spectrum of activity and relatively low-cost (Fields and White, 2002). However, it was banned in developed countries since 2005 and since 2007 in Turkey under the directive of the

Montreal Protocol on Substances that Deplete Ozone Layer (Schneider et al., 2003) stimulating the research work on seeking environmentally sound, user-friendly, effective and economic alternatives to methyl bromide. There are many research works performed to test fumigants, non-chemical, and chemical prevention methods against various pests in different commodities (Fields and White, 2002; Schneider et al., 2003; Aksoy et al., 2004).

Although controlled atmospheres (CA) have been considered as alternative to MB fumigation, at normal ambient temperatures, they have the limitation of long exposure times required for complete mortality (Navarro and Jay, 1987). However, the required exposure period may be comparable to phosphine fumigation (Navarro and Donahaye, 1990). The efficiency of CO_2 depends on the gas concentration, exposure period, temperature, moisture content of the product, pest species and life stage (Jay, 1984). Applying modified atmosphere under high pressure (20-25 bars) conditions are shown to shorten the required exposure period however its use is limited to high-value crops because of high investment in equipment and operation costs (Adler et al., 2000).

This study was performed as a part of the project that seeks MB alternatives suitable for the dried figs sector by testing application of CO_2 at atmospheric or high pressure conditions for the disinfestation of *Ephestia cautella* and *Carpoglyphus lactis,* and determination of their effects on dried figs quality.

MATERIALS AND METHODS

The CO_2 treatments at atmospheric or high pressure conditions were carried out on sun-dried fruit of Sarılop (= Calimyrna) fig variety. Each variable had a control group of MB treated (60 $g.m^{-3}$ for 24 h) fruit to compare impact of treatments on dried fruit quality. The atmospheric CO_2 was maintained for 7 days in a flexible gas-tight PVC storage unit (Volcani Cube™ or GrainPro Cocoon®) with a volume of 36 m^3 (capacity of 15 tonnes of dried figs). CO_2 and O_2 concentrations were daily monitored using a thermal conductivity detector (CO_2 analyzer Model 20-600, Gow-Mac Inst, USA), and an electrochemical detector (O_2 analyzer Model OxyCheck 2, David Bishop Ins., UK) at three different levels (0.8 ± 0.4% O_2, 94 ± 3% CO_2) of the PVC storage unit. Carbon dioxide treatment under high pressure was performed at commercial scale in two pressurized tanks (BuseGastek Company, Badhöningen, Germany), each of 20 m^3 capacity, by using exposures of 2, 3 and 5 h at 25 bar pressure.

The fruits treated with CO_2 or MB in 25 kg boxes (37 x 53x 31 cm) were further stored at ambient conditions for 2.5 months. Six boxes were randomly taken from each treated lot and 5 kg of composite samples were used per replicate. Water activity, surface color, moisture content, total soluble solids and sugaring were analyzed to assess fruit quality. Quality parameters were checked in 4 replicates immediately after treatment and at the end of storage.

Test organisms comprised different life stages (0-24, 24-48, 48-72 h old eggs, larvae, pupae and adults) of *E. cautella* and mixed stages of *C. lactis*. Test species were placed, prior to sealing, at various locations of the cube in 100 mL perforated plastic containers possessing food. After each treatment, test insects were further transferred to the laboratory and kept at 25°C and 65% r.h. Mortality of the active stages was determined 14 days after the end of trials. Eggs and pupae mortality were determined as a failure of hatch 10 days after the end of each exposure period.

Water activity was measured by a water activity meter (TH 500, Novosina, Pfaeffikon, Switzerland) at 25°C. Moisture content was based on nominal moisture content and calculated as the percentage of water lost after 24 h of drying in a vacuum oven (VD23, Binder, Germany) at 70°C. Total Soluble Solids were quantified using a refractometer (ATC-1, Atago, Japan) and expressed as %. Sugaring was assessed on a 1–5 scale, each class describing the fruit surface area covered by white sugar crystals (Aksoy et al., 2004).

The experiments were conducted as completely randomized design with four replicates. Significant differences among groups were determined using Duncan's multiple range tests at $P \leq 0.05$. All computation and statistical analyses were done using SPSS (SPSS, Inc., Chicago, IL, USA) package version 19.0.

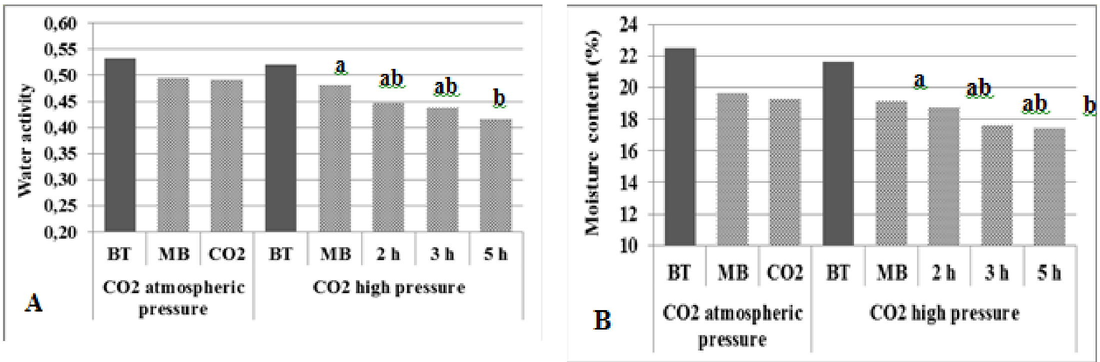

Fig. 1- Effect of 94% CO_2 at atmospheric pressure for 7 days, at 25 bar pressure for 2, 3 ad 5 h, and MB treatment on water activity (A) and moisture content (B) values after 2.5 months of storage. BT=before treatment; Significant differences of exposure to CO_2 at high pressure at $p< 0.05$ level were indicated by different letters at top of histograms.

RESULTS AND DISCUSSION

All tested variables of CO_2 and MB provided complete mortality of all stages of *E. cautella* and *C. lactis* including eggs and pupae. At high CO_2 conditions high insect mortality could be obtained in comparatively short exposure times (Navarro and Donahaye 1990).

Water activity and moisture contents of dried figs were affected only at CO_2 application under high pressure (Fig. 2A, B). Exposure to 5 h was significantly different than 2 and 3 h which were grouped together with MB treated figs. The water activity (a_w) of dried fig was relatively low thus most chemical and biochemical reactions, as well as microbiological growth, were inhibited at low a_w (Rahman and Labuza, 1999).

CO_2 applied at atmospheric pressure exerted no negative effects on color of dried figs after 2.5 months of storage and were statistically similar to the MB treated fruits. On the other hand CO_2 application for exposures varying between 2 to 5 h under high pressure lowered L*, b* and C* values significantly. Exposure to CO_2 for 5 h under high pressure resulted higher reduction in b* and C* values (Fig. 2).

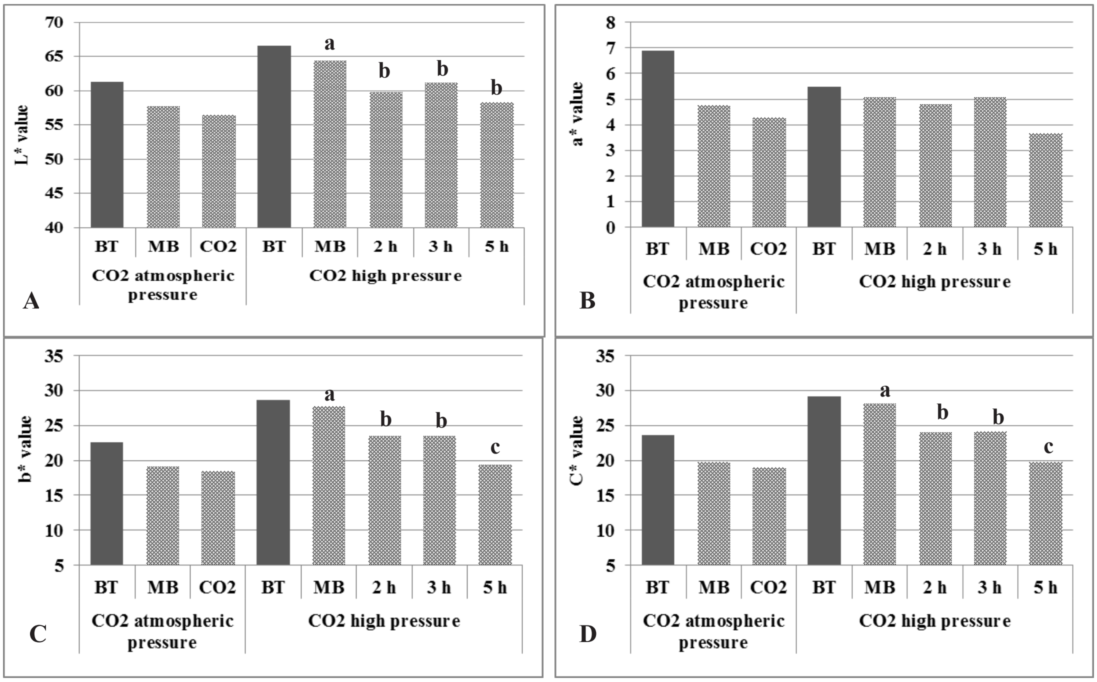

Fig. 2- Effect of 94% CO_2 at atmospheric pressure for 7 days, at 25 bar pressure for 2, 3 ad 5 h, and MB treatment on fruit colour L* (A), a* (B), b* (C) and C* (D) values after 2.5 months of storage. BT=before treatment; Significant differences of exposure to CO_2 at high pressure at $p< 0.05$ level are indicated by different letters at top of histograms.

The reduction in colour values show slightly darker and dull colour of dried figs treated with CO_2 at high pressure. This effect was found significant in quantitative analysis but not in visual evaluation. CO_2 had no significant effect on a* and h^o values. Color is accepted as an important quality attribute for Turkish figs which are known for their light colour. Darkening of the fruit colour and sugaring are the major quality attributes affected by the storage conditions. According to Meyvacı et al. (2003), fig fruits darken even if stored in packages containing CO_2 (as passive modified atmosphere packaging) at atmospheric pressure and ambient temperature for 7.5 months.

The tested variables did not have statistically significant effect on TSS content (Fig. 3 A). According to Fennema, (1976), dried figs lose their quality in storage and the rate of deterioration is dependent on the duration of storage and the prevailing temperature and relative humidity conditions. Atmospheric CO_2 application did not have any effect on sugaring (Fig 3 B). At 25 bar pressure sugaring was enhanced with increased exposure period (Fig. 3B). During 2.5 month storage, sugaring, a natural process under ambient conditions occurred on fruits exposed to all treatments. Incidence and severity of sugaring increase with storage temperature and time (Mitcham et al., 2012). Although sugaring has no risk in respect to food safety, in some cases consumers may consider it as a serious defect.

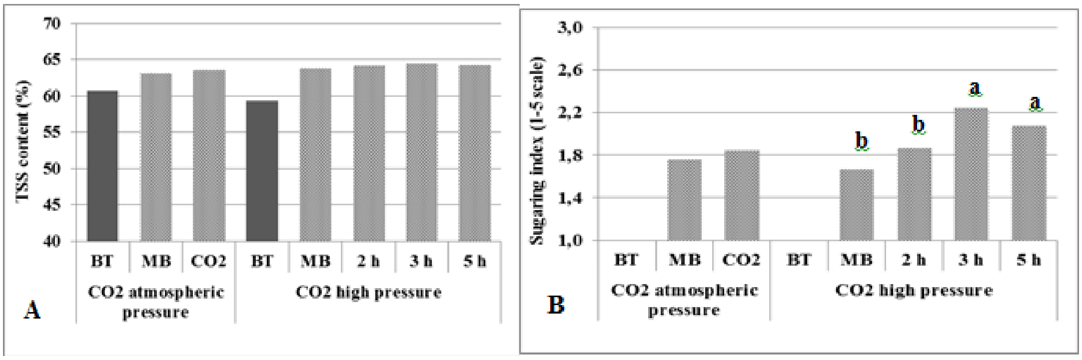

Fig. 3- Effect of 94% CO_2 at atmospheric pressure for 7 days, at 25 bar pressure for 2, 3 ad 5 h, and MB treatment on TSS content (A) and sugaring index (B) values after 2.5 months of storage. BT=before treatment; Significant differences of exposure to CO_2 at high pressure at $p< 0.05$ level are indicated by different letters at top of histograms.

Evaluation of the results obtained in the present research reveals that CO_2 at atmospheric pressure can be utilized to maintain dried figs quality in storage. In addition, it serves as short term fumigation of dried figs. The gas-tight Volcani Cube™ can be suitable during early season when the storage capacity can be a limiting factor in the processing plants of the Turkish dry figs sector. Since most of the crop is processed and exported until Christmas, a good management plan is required to supply the processing lines with good quality of figs.

High pressure CO_2 applications are expensive as alternatives to MB for dried fruits disinfestation but can be accepted as a viable alternative when short exposures are crucial. CO_2 may have an additional advantage in case of organic production since it is allowed in Turkish and other national regulations governing organic production.

ACKNOWLEDGMENT

The research is a part of the project (TTGV-P2/30m) entitled “Project to Phase-out Methyl Bromide in the Dried Fig Sector in Turkey” funded by the World Bank through the Multilateral Funds for the Implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer.

REFERENCES

Aksoy U, Meyvacı KB, Şen F, Altındişli A (2004) Impact of fumigants applied to control storage pests on fruit quality of dried figs. IOBC WPRS Bulletin. 27(9): 203-209.

Anonymous (2006) TS 541, Dried Fig, ICS 67.080.10. Turkish Standard Institute, Ankara.

Adler C, Corinth HG, Reichmuth CH (2000) Modified atmospheres. In: Subramanyam BH, Hagstrum D (Eds) Alternatives to Pesticides in Stored Product, Kluwer Academic Publ. Group, pp. 105-146.

Bell CH (2000) Fumigation in the 21st century. Crop Protection 19: 563-569.

Eliopoulos PA, Athanassiou CG (2004) Seasonal occurrence of dried fig pests and their parasitoids in a fig warehouse in Greece. IOBC WPRS Bulletin. 27(9): 159-171.

Fennema OR (1976). Principles of Food Science, Part I. Food Chemistry. Marcel Decker Inc., New York.

Fields PG, White NDG (2002) Alternatives to methyl bromide treatments for stored-product and quarantine insects. Ann. Rev. Entomol. 47: 331-359.

Jay EG (1984) Imperfections in our current knowledge of insect biology as related to their responses to controlled atmospheres. In: Ripp BE, Banks HJ, Bond EJ, Calverley DJ, Jay EG, Navarro S (Eds) Controlled Atmosphere and Fumigation in Grain Storages, Elsewier, Amsterdam, pp. 493-508.

Mitcham EJ, Crisosto CH, Kader AA (2012) Dried fruits and nuts: Recommendations for maintaining postharvest quality, http://postharvest.ucdavis.edu/PFfruits/DriedFruitsNuts/. Accessed 14 June 2012

Meyvacı KB, Şen F, Aksoy U, Altındişli A, Emekçi M, Ferizli AG (2003) Project to phase-out methyl bromide in the dried fig sector in Turkey. Acta Hort. 628: 73-81.

Navarro S, Jay E (1987) Application of modified atmospheres for controlling stored grain insects. Proc. British Crop Protection Council, No. 37 Stored Products Pest Control. Univ. of Reading. pp. 229-236.

Navarro S, Donahaye E (1990) Generation and application of modified atmospheres and fumigants for the control of storage insects. In Champ BR, Highley H, Banks HJ (Eds) Fumigation and Controlled Atmosphere Storage of Grain, ACIAR Proceedings No. 25, Singapore, pp. 152-165.

Rahman MS, Labuza TP (1999) Water activity and food preservation. In: Rahman MS (Ed) In Handbook of Food Preservation, Marcel Dekker, NY, USA, pp. 339-382.

Schneider SM, Rosskopf EN, Leesch JG, Chellemi DO, Bull CT, Mazzola M (2003) Research on alternatives to methyl bromide: pre-plant and post-harvest. Pest Management Science, 59: 814-826.

Smilanick JM (1979) Colonization ofripening figs by *Carpophilus* spp. J. Econ. Entomol. 72:557559.

Turanli F (2003) Studies on infestation levels of pests on dried fig in Aydın and Izmir provinces. Turkish J. Entomol. 27: 171-180.