Donahaye, E.J., Navarro, S., Bell, C., Jayas, D., Noyes, R., Phillips, T.W. [Eds.] (2007) Proc. Int. Conf. Controlled Atmosphere and Fumigation in Stored Products, Gold-Coast Australia. 29 Oct. - 3 Nov. 2000. FTIC Ltd. Publishing, Israel. p. 119

THE USE OF MODIFIED ATMOSPHERES FOR CONTROLLING ALMOND MOTH, *EPHESTIA CAUTELLA* (WALKER) (LEPIDOPTERA : PYRALIDAE)

S. TÜTÜNCÜ[1], M. EMEKCI[1] AND S. NAVARRO[2]

[1]*Ankara University, Faculty of Agriculture, Department of Plant Protection, 06110 Ankara / Turkey; [*]E-mail: suletutuncu@hotmail.com*
[2] *Department of Food Science, Agricultural Research Organization, The Volcani Center, P.O.Box 6, Bet Dagan 50250, Israel*

ABSTRACT

Eggs 1-3 days-old, young - mature larvae, 1-3 day-old pupae and 1 day-old adults of the almond moth, *Ephestia cautella* were exposed to 90% and 96% CO_2 (balance normal air) at 20, 27.5 and 32.5ºC temperatures, and at 65%±5 r.h. for different exposure periods to test the effectiveness of high CO_2 levels on almond moth mortality. According to the results of the tests conducted at 90% CO_2, complete mortalities of eggs at 27.5ºC and 32.5ºC were recorded after 48 and 36 hours of exposure, respectively. When the CO_2 level increased to 96%, total mortality time at 27.5ºC and 32.5 was found to be 38 and 32 hours respectively.

Eight hours of exposure at 27.5 and 32.5ºC and at both CO_2 levels was found to be sufficient to kill all 10 day-old young larvae. At 90% CO_2, complete kill of 20 day-old mature larvae at 27.5 and 32.5ºC was observed within 36 and 26 hours of exposure, respectively; while at 96% CO_2, the exposure times required were 28 and 26 hours, respectively. Complete mortality of pupae at 90% CO_2 was obtained at 27.5ºC and 32.5ºC within 36 and 28 hours, respectively. When the CO_2 level increased to 96%, total mortality at 27.5ºC and 32.5ºC was achieved after 32 and 24 hours, respectively. A 24-hour exposure period was found to be sufficient to kill all adults at both temperatures and at both CO_2 levels.

Results clearly indicate that at higher temperatures, CO_2 applications are very effective against almond moth in quite short exposure times and can be regarded as an alternative to MeBr in situations such as treatment of dried figs in processing plants where the pest constitutes the main problem during the dried fig season in Turkey.

INTRODUCTION

The Almond moth, *Ephestia cautella* (Walker) is the main pest of dried figs in the Aegean region and shelled hazelnuts in the Black Sea region of Turkey (Anonymous, 1995). Turkey is the leading player in the world trade of dried figs and hazelnuts. Historical documents reveal that hazelnuts have been grown along the Black Sea coast in northern Turkey since 300 B.C., and Turkey competes with Spain, Italy, and the United States in the international markets. In 2004, Turkish hazelnut exports reached 217.650 tons with a value of US $ 1.220.695. Turkey also leads the world in figs, producing 36 percent of the world's total production and accounting for 70-75 percent of total world exports. Turkish dried fig exports in 2004 were 49,073 tons with a value of US $ 85.596.

Disinfestations of dried figs in particular depend highly on methyl bromide (MBr) use in the processing plants in Turkey. According to an action plan, MBr use in Turkey for post-harvest commodities will be completely banned in 2004, which means that the industry will remain without applicable MBr alternatives, Consequently, Turkey might soon face a production and export bottleneck for dried figs.

Many researchers have emphasized that modified atmosphere (MA) applications are important candidates for MBr replacement against dried fruits pests (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; Navarro *et al*., 2002). High carbon dioxide applications were shown to cause a complete kill of some stored product pests within 24-48 h with the help of an increased temperature of 38ºC or above (Jay, 1984, 1986). Similarly, Navarro and Donahaye (1990) reported that higher insect mortality could be obtained in comparatively short exposure times at high CO_2 atmospheres than at low oxygen applications.

Thus, the objective of this research was to determine the mortality times of the different life stages of the almond moth exposed to high CO_2 in the laboratory at different temperatures in order to evaluate the possibility of using MA as an alternative to MBr.

MATERIALS AND METHODS

Insect rearing. Almond moths used for these experiments were raised in the laboratory at 25ºC and 65% r.h. Eggs were collected daily from 2.5-l PVC jars in which 50 to 100 young adults were placed. From 0-24 h eggs, successive larval cultures were set-up to obtain larvae and pupae of known ages for the experiments. Larvae that reached their appropriate age interval were separated from the cultures. Pupae were obtained by means of polyethylene transparent tubes of 2.0–2.5mm i.d. x 7 mm long which were placed in the rearing jar at the time when the larvae begin to wander, as proposed by Navarro and Gonen, 1970. With daily checking, 1–3 day-old pupae inside the tubes were collected and placed in the gas exposure bottles.

Modified atmospheres. The mortalities of the almond moth were tested in an atmosphere composed of 96% CO_2 in air at 27.5 and 32.5 ± 1°C. Normal air served as a control. Gas mixtures were obtained from pre-mixed pressurized steel cylinders supplied by Karbogaz Inc. (Gebze/Turkey), and maintained at a rate of 100 ml/min at 65% r.h. The different development stages, the number of individuals and age groups of almond moth used in mortality tests are shown in Table 1.

Exposure flasks. One liter gas-washing bottles having an inlet and outlet served as exposure flasks. Known numbers of test individuals (Table 1) in special vials were transferred to the experimental bottles, which were then connected to the exposure apparatus. During the flushing period, gas concentrations inside the bottles were checked with the aid of CO_2 and O_2 analyzers (Gow Mac CO_2 analyzer Model 20-600; David Bishop Inst. O_2 analyzer Model OxyCheck 2) attached to the outlet needle of each bottle. When the desired CO_2 level was reached, the inlet and outlet ports of the bottles were then blocked tightly. Tests were replicated three times.

TABLE 1 Numbers and the ages of *Ephestia cautella* according to the developmental stages used for testing their mortality

Developmental stage	Age of insects (days)*	Numbers per replicate
Eggs	0-3	100
Young larvae	7–10	50
Old larvae	18–22	50
Pupae	0–3	50
Adults	0-1	25

*Age for larval stages from egg stage; pupae from pupation; and adults from emergence

RESULTS AND DISCUSSION

Exposure periods to obtain a total mortality of different life stages of the almond moth are shown in Fig. 1. Eggs were the most resistant stage to high CO_2 applications followed by pupae, old larvae, and adults. Young larvae on the other hand were the most sensitive stages to high CO_2 atmospheres. Results show that 48 h of exposure were sufficient to reach a complete mortality of the most resistant egg stage at 90% CO_2 at 27.5°C. Increase in CO_2 and temperature decreased the complete mortality time for eggs, old larvae and pupae, while it did not make any significant change in the responses of young larvae and adults.

Jay (1984) reported that at 63% CO_2 in air at 27°C and 66% r.h., eggs, larvae and pupae of the almond moth were killed in 2, 5 and 3 days respectively. In our study at 90% CO_2 at 27.5°C and 65% r.h. mortalities for the same order were found as 48, 32, and 36 h, respectively. The differences between the mortality time observed in both studies can be attributed to the differences in CO_2 concentrations. On the other hand, Bell *et al.* (2003) reported that the complete mortality time of the eggs (at 34°C), larvae (at 36°C), and pupae (at 36°C) of *E. cautella* exposed to a low oxygen atmosphere composed of 0.5% oxygen and 13% carbon dioxide in nitrogen were only16 hours. The differences in gas compositions and temperatures probably lead to such differences in mortality times obtained in the different studies. However, all the studies mentioned here suggest the possibility of using modified atmospheres as an alternative to MBr to obtain complete mortality of the almond moth *E. cautella* in relatively short exposure periods.

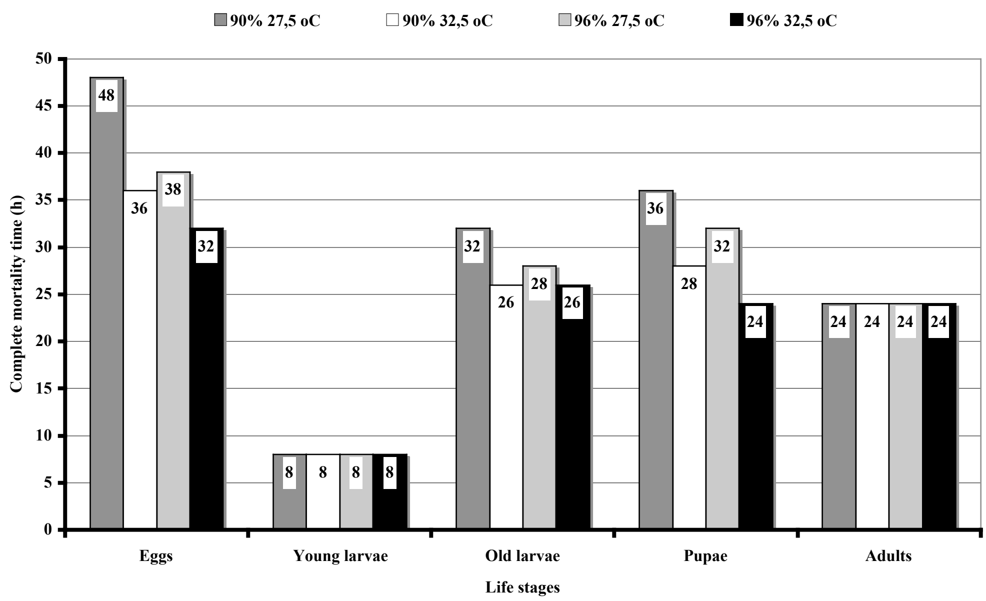

Figure 1. Complete mortality time (h) of different life stages of *Ephestia cautella* exposed to 96% CO_2 at 27.5 and 32.5°C at 65% r.h.

ACKNOWLEDGEMENTS

This research was partially supported through the projects entitled "*Project to Phase-Out Methyl Bromide in the Dried Fig Sector in Turkey* (TTGV-P2/30m)" funded by the World Bank through the Multilateral Funds for the Implementation of the

Montreal Protocol on Substances that Deplete the Ozone Layer; and "*Mites infesting stored products in Diyarbakir and Sanliurfa provinces and their control* (TARP 1848)" funded by The Scientific and Technical Research Council of Turkey (TUBITAK). We also wish to express our appreciation to TARIS and the Aegean Exporters' Union for their valuable assistance during the course of the experiments.

REFERENCES

Anonymous, (1995) Plant Protection Technical Instructions. V 1-5. Ministry of Agriculture and Rural Affairs, General Directorate of Plant Protection. Ankara.

Bell C.H., Harral B.B., Wontner Smith T.J., Conyers S.T., Mills K.A., Cardwell S.K. and Llewellin B.E. (2003) Modified atmospheres at raised temperature, an alternative to methyl bromide as a means of ensuring clean, pest-free, hygienic standards in food commodities. Report for LINK project AFM87.

Donahaye, E., Navarro, S. and Rindner M. (1994) The influence of temperature on the sensitivity of two nitidulid beetles to low oxygen concentrations. In: Proc. 6th Int. wkg. Conf. Stored-Product Protection, 17-23 April 1994 Canberra Australia 1, 88-90.

Donahaye, E., Navarro, S., Rindner M. and Azrieli, A. (1998) Quality preservation of stored dry fruit by carbon dioxide enriched atmospheres. Proc. Annual Int. Res. Conf. Methyl Bromide Alternatives and Emission Reductions, 7-9 December 1998, Orlando Florida pp. 89/1 – 89/3.

Jay, E.G. (1984) Imperfections in our current knowledge of insect biology as related to their responses to controlled atmospheres. In: Controlled Atmosphere and Fumigation in Grain Storages (Edited by: Ripp, B.E., Banks, H.J., Bond, E.J., Calverley, D.J., Jay, E.G., and Navarro, S.), Elsewier, Amsterdam, 493-508.

Jay, E.G. (1986) Factors affecting the use of carbon dioxide for treating raw and processed agricultural products. GASGA Seminar on Fumigation Technology in Developing Countries. Tropical Development and Research Institute, London, pp 173-189.

Navarro S., Finkelman S., Donahaye E., Dias R., Rindner M. and Azrieli A. (2002) Integrated storage pest control methods using vacuum or CO_2 in transportable systems. In: Proceedings of the IOBC WPRS Working Group "Integrated Protection in Stored Products", (Edited by: C. Adler, S. Navarro, M. Schöller and L. Stengard-Hansen, 2002) Lisbon, Portugal, 3-5 September, 2001 p. 31. Bulletin OILB SROP 25(3), 207-213.

Navarro, S. and Donahaye, E., (1990) Generation and application of modified and fumigants for the control of storage insects.. In: Fumigation and controlled atmosphere storage of grain. Proceedings of an International Conference, (Edited by: Champ, B.R., Highley, E., and Banks, H.J.), Singapore, 14-18 February 1989. ACIAR Proceedings No. 25, pp. 152-165.

Navarro, S., Donahaye E., Rindner M., and Azrieli A., (1998a) Storage of dried fruits under controlled atmosphere for preservation and control of nitidulid beetles. *Acta Hort.* **480**, 221-226.

Navarro, S., Donahaye, E., Rindner, M. and Azrieli A. (2000) Storage of dates under carbon dioxide atmosphere for quality preservation. In: Proc. Int. Conf. Controlled Atmosphere and Fumigation in Stored Products, (Edited by: Donahaye, E.J., Navarro, S. and Leesch J.G.), Fresno, CA. 29 Oct. - 3 Nov. (2000) Executive Printing Services, Clovis, CA, U.S.A. pp. 307-315

Navarro, S., Donahaye, E., Rindner, M. and Azrieli, A. (1998b) Disinfestation of nitidulid beetles from dried fruits by modified atmospheres. Proc. Annual Int. Res. Conf. Methyl Bromide Alternatives and Emission Reductions, 7-9 December 1998, Orlando Florida pp.68_1 - 68_3.

Navarro, S., Donahaye, E., Rindner, M., Dias, R. and Azrieli A. (1993) Integration of controlled atmosphere and low temperature for disinfestation and control of dried fruit beetles In: Proc. Int. Conf. Controlled Atmosphere and Fumigation in Grain Storages, Winnipeg, Canada June 1992, pp. 389-398.

Soderstrom, E. L., Gardner, P. D., Baritelle J. L., de Lozano, K. N. and Brandl, D. G. (1984) Economic cost evaluation of a generated low-oxygen atmosphere as an alternative fumigant in the bulk storage of raisins *J. Econ. Entomol.* **77**, 457-461.

Soderstrom, E.L., Mackey, B.E. and Brandl, D.G. (1986) Interactive effects of low-oxygen atmospheres, relative humidity and temperature on mortality of two stored product moths (Lepidoptera, Pyralidae). *J. Econ Entomol.* **79,** 1303-1306.

Tarr, C., Hilton, S.J., van S. Graver J., and Clingeleffer P.R., (1994) Carbon dioxide fumigation of processed dried vine fruit (sultanas) in sealed stacks. In: Proc. 6th Int. Working Conf. on Stored-Product Protection (Edited by: Highley, E., Wright, E.J., Banks, H.J. and Champ, B.R), Canberra, Australia, 17-23 April 1994, CAB International, Wallingford, Oxon, UK, pp .1, 204-209.