PRACTICAL ALTERNATIVES TO METHYL BROMIDE FOR USE AS QUARANTINE AND PRE-SHIPMENT TREATMENTS IN NORTH AMERICA.

P. G. FIELDS[1], L. G. NEVEN[2] AND J. JOHNSON[3]
[1] Cereal Research Centre, Agriculture and Agri-Food Canada; [2] Yakima Agricultural Research Laboratory, USDA-ARS; [3] San Joaquin Valley Agricultural Sciences Center, USDA-ARS
Corresponding author: pfields@agr.gc.ca

ABSTRACT

We present recent advances in quarantine and pre-shipment alternatives: phosphine and methyl bromide recapture for empty ship holds; radio frequency heating in walnuts; low oxygen followed by low oxygen, cold or virus treatment to disinfest dried fruits and nuts; controlled atmosphere temperature treatment system (CATTS) for fresh fruit.

Keywords: insects, QPS, control atmospheres, heat, cold, irradiation.

INTRODUCTION

For most countries methyl bromide is still the method of choice to deal with quarantine pests. As quarantine and pre-shipment (QPS) treatments are exempt under the Montreal Protocol, there has been less research into developing alternative treatments. However, the European Community has capped its use of methyl bromide in 2001, and it has committed to reducing its QPS consumption. There are concerns that methyl bromide will eventually be unavailable for QPS because of regulatory restrictions, or the cost will become too expensive. Hence there is an interest to develop alternatives for QPS uses.

Quarantine uses of methyl bromide are distinct from other methyl bromide uses in that they are mandated by government authorities, against a pest that could be introduced to the receiving country or region. Therefore the level of control required is much greater than regular treatments in places such as flour mills or strawberry fields. Pre-shipment uses of methyl bromide are defined as uses of methyl bromide done within 21 days of export, mandated by government authorities and are required to maintain the quality of the product. Detailed definitions are found in the 2002 Methyl Bromide Technical Options Report.

In 2000, globally about 20% of methyl bromide was used for QPS treatments; durables (2100 mt), timber (3900 mt) and perishables (4500 mt) (MBTOC 2002). The non-QPS uses for the USA in 1997 was 20,520 mt, QPS in the USA is only about 1% of total use. In Canada the non-QPS uses were 142 mt, making QPS in Canada about 8% of total use. In Canada in 2003, 17 mt were used for QPS, 75% of this being used for commodities imported into Canada, the other major uses were; empty grain ships (8%) or export (14%). The USA used 260 to 294 mt/yr between 1996 and 1998 (Vick & Schneider 2002), with about equal amounts being used for export and import. The following uses were recorded for export; fruits and nuts (50%), dunnage (19%, this is known to be underestimated), logs (17%) and cotton (11%). The main uses listed for imported goods are; fruit (56%), cotton (11%) and vegetables (12%).

Some common QPS treatments that do not use methyl bromide are: irradiation, heat, cold, systems approach, pest free zones/seasons, controlled atmospheres, physical removal and other chemicals. There have been a number of recent reviews of alternatives to methyl bromide for QPS treatments (Dowdy 2002, Fields & White 2002, MBTOC 2002), so we have limited the information presented here to some recent advances in the field.

EMPTY SHIP HOLD TREATMENTS

In Canada, grain is exported with zero tolerance for live grain-feeding insects. To this end, it is illegal to transport grain in vessels (trucks, rail cars or ships) that are already infested. Ships are inspected before grain is loaded into the holds. On average there are 1000 grain ships inspected each year and about 20 ships a year are fumigated with methyl bromide because of infestations. Methyl bromide is used because it is effective; rapid (reducing the demurrage charges which can be $10,000/day), and works at low temperatures.

Three alternative methods were tried in an empty ship; cylinderized phosphine (ECO$_2$FUME, 2% PH_3, with 98% CO_2), phosphine generator ($MgPH_3$ powder) and methyl bromide with recapture after the fumigation. Phosphine, a common grain fumigant, is usually applied as tablets of $AlPH_3$, but this method is much slower than methods we used. The final concentrations were 500 ppm PH_3 for the ECO$_2$FUME, 1000 ppm PH_3 for the phosphine generator, and 5400 ppm of methyl bromide for the methyl bromide recapture test. Four common stored grain insect pests (red flour beetle, *Tribolium castaneum;* rice weevil, *Sitophilus oryzae*; lesser grain borer, *Rhyzopertha domincia*; rusty grain beetle, *Cryptolestes ferrugineus*) were placed in vials in the ship holds, 25 adults, and an unknown number of eggs had been laid in the grain.

All adults died within 32 hours in all of the treatments. No red flour beetles eggs were alive after 32 hours exposure. The phosphine treatments controlled at least 94% of the rice weevil and lesser grain borer eggs after 32 hours, 99% after 48 hours and 100% after 72 hours (Fields & Jones 1999).

Air from the ship hold treated with methyl bromide was pulled through a zeolite bed at the end of the fumigation. Zeolite can hold 4-6% of its weight in methyl bromide. Over 80% of the methyl bromide was captured on the sieve. No extra time was needed to capture the methyl bromide as compared to venting. Advantages of recapture are; less methyl bromide vented, less hazard to workers and little change from present practice of methyl bromide fumigation.

RADIO FREQUENCIES TO CONTROL INSECTS IN WALNUTS

Codling moth (*Cydia pomonella*), navel orangeworm (*Amyelois transitella*) and Indianmeal moth (*Plodia interpunctella*) are common insect pests in walnuts in California, USA. Currently, successful export of in-shell walnuts requires treatment with methyl bromide before shipment. However, except for product destined for Japan, methyl bromide fumigation of walnuts is not considered a quarantine treatment. We felt that heat treatments described here may have potential both for quarantine and non-quarantine treatments.

Radio frequency (RF) has been used for drying and heating in numerous industries, including textiles, food processing, woodworking, paper processing and plastics. Industrial radio frequencies range from 10 to 100 MHz. Unlike X-rays and gamma rays that can alter molecular structures, RF is “non-ionizing” radiation, heating product much like microwave radiation. Because RF treatments rapidly heat product throughout, insecticidal temperatures are more easily reached without causing product damage.

Walnuts were heated with RF at 5^{o}C/min. to 47, 50, 53 and 55^{o}C causing 32, 77, 99 and 100% mortality respectively of fifth instar navel orangeworm. This insect and stage were chosen because it was the most heat tolerant of the possible pests. Heating with RF caused no adverse effects on walnut quality (Mitcham et al. 2004).

COMBINATION OF LOW OXYGEN FOLLOWED BY PREVENTIVE TREATMENTS

Pyralid moths are a major problem in dried fruits and nuts in California, USA. Navel orangeworm and raisin moth (*Cadra figulilella*) infestations begin in the field, though these pests do not reproduce in storage. The Indianmeal moth populations increase with time in storage if not held in check by control methods. A non-chemical treatment schedule was designed to address these various pests (Johnson et al. 1998, 2002).

Initial disinfestation of the navel orangeworm and the raisin moth was carried out by treating commercially harvested almonds (lots of 227 kg) , walnuts (lots of 225 kg) or raisins (lots of 1800 kg) with 0.4% oxygen for 6 days at 25^{o}C. This treatment was followed by one of three preventive treatments; 5% oxygen, cold storage at 10^{o}C or treatment with Indianmeal moth granulosis virus. Indianmeal moth adults were released weekly into the treatments.

The initial low oxygen disinfestation reduced populations of navel orangeworm and raisin moth between 100 and 90%. Indianmeal moth developed rapidly in the untreated products, with pheromone traps catching between 50 and 800 adults/week. A total of less than 22 adults were found in the low oxygen and cold storage during the entire trapping period (13 – 40 weeks). These adults were probably coming from outside the test enclosures, as no damage or larvae were found in the product. In the treatment with granulosis virus, there was a low level of moths trapped and larvae found in the product, 10% or less than in the untreated product (Johnson et al. 1998, 2002).

COMBINATION HOT FORCED AIR WITH CONTROLLED ATMOSPHERES

A collaborative project with Elizabeth Mitcham (University of California, Davis), Lisa Neven (USDA-ARS in Wapato, WA) and Dan Black (Techni-Systems, Chelan, WA) developed a research unit that can treat commodities with hot forced moist air or vapor heat while monitoring and controlling the rate of heating, surface and core temperatures, relative humidity, dew point, air speed, oxygen and carbon dioxide levels (Neven & Mitcham 1996). They called this technology CATTS for Controlled Atmosphere Temperature Treatment System, and is similar to system developed in New Zealand. There are now research-scale CATTS units in Washington, California, Hawaii, Texas, Mexico and Israel. A 2-tonne commercial scale unit is being tested in George, WA.

CATTS was developed to exploit the differences in stress responses of plants versus insects to control insect pests without damaging fruit. A heat shocked plant is more resistant to chilling than one which never received a heat shock (Neven et al. 1993). Insects, on the other hand, do not generally exhibit this response scenario. In addition, plants are more tolerant of low oxygen environments than are insects.

Traditionally, heat treatments have been conducted to reach the target temperature as quickly as possible. This strategy works effectively for tropical and sub-tropical fruits, but not for temperate tree fruits (Neven et al. 1996). The lower limit of the optimal rate of heating for apples and pears reflected the heating rate of the fruit on the tree during a hot summers' day. Fruit can respond to the heat load in a direct postharvest treatment if it is not far from the cyclical heat load experienced during the growing season. While heating rate needs to be optimized to preserve fruit quality, the effects on insect mortality are also paramount. The slower the rate of heating, and the lower the final treatment temperature, the longer the total treatment needs to be to control the insect pest (Neven et al. 1996). A treatment matrix for codling moth mortality and apple quality that incorporates heating rate, final treatment temperature, and duration was developed (Neven & Drake 2000). This guideline was used to develop combination treatments for apples, winter pears, peaches, nectarines and Bartlett pears.

Fruit and insects were subjected to heat treatments with and without controlled atmospheres (CA) (1% O_2, 15% CO_2) with a linear heating rate of 12°C to final treatment temperatures of either 44 or 46°C for 4 or 3 hours. Dew point was controlled to 2°C above the surface temperature of the fruit. Air speed was maintained between 1.5 and 2.0 m/s. Codling moth larvae (fourth instar), the stage most tolerant to heat and controlled atmosphere treatments, were transferred to the fruit 24 hours prior to the test. Codling moth infested fruit were evaluated the day after treatment and moribund larvae were held on artificial diet for 7 days and evaluated for survival. Following treatment, all fruit that were to be evaluated for quality were stored under standard CA conditions (1% O_2, 1% CO_2, 0°C) for 0, 45 or 90 days. No significant differences were detected in fruit quality for fruit heated in air or under CA conditions. In all heat-treated fruit, quality after cold storage was as good or better than fruit that were not heat-treated. The results from this test were similar to those obtained in previous studies using fruit heated in air (Neven & Drake, 2000).

The impact of application of the controlled atmosphere during the heat treatment on insect mortality is significant. Heat treatments without the addition of the controlled atmosphere gave 55% mortality of the fourth instar codling moth after 3 hours of treatment (using the 46°C treatment), whereas heat treatment accompanied with a controlled atmosphere gave 100% mortality.

Successful research scale trials have been carried out on: sweet cherries with codling moth and Western cherry fruit fly; peaches and nectarines with codling moth and Oriental fruit moth; mangoes in Mexico for fruit flies.

REFERENCES

Dowdy, A.K. 2002: Use of non-chemical methyl bromide alternatives in the USA. *In:* Batchelor, T.A.; Bolivar, J.M. *ed.* Proc. Int. Confer. Alt. Methyl Bromide. Sevilla, Spain. Beligum: European Commission. Pp. 107-110.

Fields, P.G.; Jones, S. 1999: Alternatives to methyl bromide fumigation of empty ship holds. Agriculture and Agri-Food Canada, Ottawa, Canada. 27 p.

Fields, P.G.; White, N.D. G. 2002: Alternatives to methyl bromide treatments for stored-product and quarantine insects. *Annu. Rev. Entomol. 47*: 331-59.

Johnson, J.A.; Vail, P.V.; Soderstrom, E.L.; Curtis, C.E.; Brandl, D.G.; Tebbets, J.S.; Valero, K.A. 1998: Integration of nonchemical postharvest treatments for control of navel orangeworm (Lepidoptera: Pyralidae) and Indianmeal moth (Lepidoptera: Pyralidae) in walnuts. *J. Econ. Entomol. 91:* 1437-1444.

Johnson, J.A.; Vail, P.V.; Brandl, D.G.; Tebbets, J.S., Valero, K.A. 2002: Integration of non-chemical treatments for control of postharvest pyralid moths (Lepidoptera: Pyralidae) in almonds and raisins. *J. Econ. Entomol. 95:* 190-199.

Methyl Bromide Technical Options Committee. 2002: 2002 Report of the Methyl Bromide Technical Options Committee, 2002 Assessment. UNEP, Nairobi, Kenya. 437 p.

Mitcham, E.J.; Veltman, R.H.; Feng, X.; de Casto, E.; Johnson, J.A.; Simpson, T.L.; Biasi, W.V.; Wang, S.; Tang, J. 2004: Application of radio frequency treatments to control insects in in-shell walnuts. *Postharv. Biol. Tech. 33*: 93-100.

Neven, L.G.; Drake, S.R. 2000: Comparison of alternative quarantine treatments for sweet cherries. *Postharv. Biol. Tech. 20:* 107-114

Neven. L.G. Mitcham, E. 1996: CATTS (Controlled Atmosphere/Temperature Treatment System): A novel tool for the development of quarantine treatments. *Amer. Entomol. 42*: 56-59.

Neven, L.G.; Haskell, D.W.; Hofig, A.; Li, Q.B.; Guy, C.L. 1993: Characterization of a gene responsive to low temperature and water stress. *J. Plant Molecular Biol. 21:* 291-305.

Neven, L.G.; Rehfield, L.M.; Shellie, K.C. 1996: Moist and vapor forced air treatments of apples and pears: Effects on the mortality of fifth instar codling moth (Lepidoptera: Tortricidae). *J Econ. Entomol. 89*: 700-704.

Vick, K.W.; Schneider, S.M. 2002: Estimated quarantine use of methyl bromide in the United States. *Pesticide Outlook 13:* 14-15.