SUMMARY OF ALTERNATIVE QUARANTINE TREATMENT RESEARCH IN THE PACIFIC NORTHWEST

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Introduction

Current research in alternative quarantine treatments for pome and stone fruits produced in the Pacific Northwest is conducted primarily at the USDA-ARS, Yakima Agricultural Research Laboratory (YARL). The insect pest which poses the most concern to importing countries is codling moth (*Cydia pomonella*). At present the only approved quarantine treatments against this pest involve fumigation with methyl bromide. Because methyl bromide is scheduled for removal from the chemical register on January 1, 2001, the development of alternative treatments to control this important quarantine pest is imperative.

Research in alternative treatments at YARL include hot forced air, both vapor and moist humidity conditions, hot air, cold storage, controlled atmospheres in combination with either high or low temperatures, microwaves, and irradiation. The effects of these treatments on the immature stages of codling moth and on fruit quality are not well understood. Various aspects of these treatments, such as heating rates, levels of oxygen and carbon dioxide, and residual effects of radiation are being investigated. The assessment of fruit quality, which is primarily apples, pears, and sweet cherries, is performed at the USDA-ARS, Tree Fruit Research Laboratory (TFRL) in Wenatchee, WA. We will briefly summarize the status of numerous projects being conducted at YARL.

Heat: High temperatures as a means of disinfesting fruits of codling moth poses many problems. The primary problem is industry acceptance. The tree fruit industry believes that once a fruit is removed from the tree, it should be cooled as quickly as possible. Industry is very resistant to heating fruit after picking and prior to storage. However, freshly harvested fruit can tolerate short-term heating quite well. We have noticed that heat treatments of apples and pears actually improve storage and sycronize ripening in pears. The most important factors for fruit quality are the method and rate of heating. Slower rates of heating are important for maintaining quality of apples and pears. Cherries, on the other hand, require a rapid heat treatment and rapid cool-down to preserve quality. The effects of heat treatments on fruit quality control the development of treatments against codling moth. We have found that the slower the rate of heating, the longer the insect must be exposed to the final treatment temperature to achieve the same levels of mortality as treatments with faster rates of heating. For example, 100% codling moth mortality in cherries that are heated to 45°C at a rate of 4.4°C/min is achieved in 60 min; whereas for apples heated to 46°C at a rate of 4°C/hr, it takes over 12 hr to achieve 100% mortality. From our research, we have developed a model which predicts insect mortality as a function of heating rate. From this model, we can develop a treatment to achieve the desired insect mortality which is based on fruit tolerance.

Combination Heat/CA: Studies involving combination heat and controlled atmospheres (CA) are conducted in a unique system called CATTS (Controlled Atmosphere Temperature Treatment System) which allows for control of atmospheric gases during heat treatments. Combining a controlled atmosphere with a heat treatment reduces the total length of a treatment by ½ to ¼. Again, the rate of heating plays an important role in the effectiveness of the combination treatments. Insect respiration is related to the environmental temperature. Studies examining the effects of heating rate on insect respiration showed that there is a strong correlation between heating rate and the limits of insect response. This relationship is useful when timing of the application of a controlled atmosphere during a heat treatment. The levels of atmospheric gases (O2 and CO_2), are important in designing combination treatments. At high temperatures, the level of O_2 is more important than CO_2. This is due to the fact that insect

respiratory control is short-circuited at high temperatures (i.e. regulation of CO_2) in combination with the increased demand for oxygen as a result of elevated metabolism. Therefore, low O_2 is more lethal at high temperatures than high CO_2.

Combination Cold/CA: Cold (-2°C) with a low oxygen (1-5%) and moderate carbon dioxide (1-5%) atmospheres is a standard commercial method of storage for northwest grown apples and pears. Codling moth 5th-instars are the most tolerant to cold storage, and take approximately 3-4 months to achieve 100% mortality. When a controlled atmosphere is combined with cold storage, mortality is enhanced for the first two months of storage. After that time, no differences in mortality are observed. Also, the higher the levels of CO_2, the more pronounced the effect on larval mortality; at least for the first two months of storage. The higher levels of CO_2 help to override control over respiration and allow the spiracles to remain open longer than would be normal at these low temperatures, thus depleting the O_2 levels in the insect, resulting in death. Studies on modified atmosphere packaging (MAP) of sweet cherries showed that although the modified atmospheres offer no more additional control of the codling moth larvae than traditional cold storage, fruit quality is preserved.

Combination Heat/Cold: We have previously reported that heat treatment followed by cold storage increases insect mortality. The more rapid the application of low temperature following a heat treatment, the more pronounced the effect. Increasing the duration of cold storage shortens the duration of the heat treatment in order to achieve the same levels of mortality. Heat treatments of codling moth must reach at least 42°C for subsequent cold storage to be effective. Combination heat/cold treatments are being 'Tailor-made' to reflect industry export and marketing demands. Cold storage durations for sweet cherries span 2-14 days whereas cold storage periods for apples and pears span 1-3 months.

Microwaves: Studies on the effects of focused microwaves on both insect mortality and fruit quality have just begun. This research is be conducted in collaboration with Dr. J. Tang at Washington State University. Dr. Tang has a research-scale focused microwave unit which operates at 915 MHz. Most home microwaves operate at 2540 MHz. The shorter wavelength has an electricity-to-heat energy efficiency of more than 90%, which is significantly higher than domestic microwaves. In preliminary tests, Dr. Tang found that 915 MHz had a penetration depth of 3.5 inches in apples whereas 2540 MHz only penetrated ¾ inches. Tests on sweet cherry quality indicated no significant damage in a 25 second treatment followed by a 2 minute hold. Preliminary tests on codling moth in sweet cherries showed 100% mortality following only a 20 second exposure followed by a hold of 2 minutes prior to hydrocooling. Although we are greatly encouraged by these results, these tests only involved a few fruits and insects. More extensive studies on fruit quality and insect mortality are needed.

Irradiation: A considerable body of research exists on the effects of radiation on codling moth, both for quarantine control and the sterile insect technique. Very little data exists on the effects of radiation on insects infesting fruit. A dose response experiment of third instar codling moth infesting sweet cherries was performed. Doses ranging from 0 to 300 Gy were tested. We found normal adult emergence in the 0 and 50 Gy treatment groups. No normal adults emerged from the 100 Gy treatment group and no adults emerged from groups which received dosed of 150 Gy or more. One major problem with irradiation as a quarantine treatment is that it does not result in insect mortality. Although insects treated at 250 and 300 Gy died more rapidly than other treatment groups, many larvae were sill living 60 days following treatment. This poses a problem if shipments of irradiated fruit are to be held to wait for 'no adult emergence'. In an effort to develop a biochemical determinant of irradiation for codling moth we examined the usefulness of testing for the activity of phenoloxidase. This procedure, which appears to be quite reliable for tropical and sub-tropical fruit flies, is not reliable for codling moth. Such a test needs to be 100% reliable for all instars treated, which was not found to be true for codling moth. Codling moth infests at a level of one larvae per fruit, unlike fruit flies which might be present in tens to hundreds. The incidence of codling

moth in the packed box exceeds 1 in 3 million, therefore any insect found must exhibit the effects of radiation (decreased melanization rate) in an all-or-none fashion. Since this was not found to hold true for codling moth, we suggest that this method not be used for determination of irradiated codling moth.