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TITLE: Irradiation and Heat Disinfestation Treatments for Apple Maggot

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OBJECTIVES:

The objective of this research was to determine the efficacy of irradiation and heat/controlled atmosphere as quarantine treatments for apples that could be at risk of infestation with apple maggot. Any treatments against apple maggot must also be effective against any other quarantine pests faced in Washington state, such as codling moth and oriental fruit moth. Work with apple maggot is coordinated with work on these other pests and work on apple quality after exposure to potential treatments so that any treatment developed will be effective against all pests of concern and not harm apple quality.

SIGNIFICANT FINDINGS:

1. Apple maggots in apples stored in low oxygen atmospheres at the time of irradiation were more tolerant of irradiation than apple maggots irradiated in apples stored in ambient atmospheres.
2. A radiation dose of 50 Gy prevents adult emergence from 3rd instar apple maggot (the most radiotolerant stage) in apples stored in low oxygen; a lower dose would do for apples not stored in low oxygen atmospheres.
3. Apples tolerate at least 700 Gy (previous research by Steve Drake); therefore, irradiation of apples for quarantine purposes against apple maggot should cause no quality loss to apples.
4. Using a standard treatment protocol developed by ARS-Yakima which should not damage apples significantly (heated air at a rate of not more than 14°C/hour; 1% oxygen and 15% carbon dioxide), apple maggot eggs were found to be the most tolerant stage to this treatment.
5. At 44°C and 46°C, respectively, 4.5 and 4 hours would be necessary to provide complete kill of apple maggot eggs in apples.

JUSTIFICATION:

The apple maggot is a serious threat to apple exports from the state of Washington. Current export protocols call for disinfestation treatments; only methyl bromide fumigation and cold treatments are available. Although methyl bromide fumigation has been rescued as a postharvest quarantine treatment by changes to U.S. law related to the Clean Air Act, the continued use of the fumigant cannot be assured because its greatest application, pre-plant fumigation, is scheduled to be phased out which may result in problems with availability and price for postharvest uses in the future. The price of the fumigant has tripled in recent years. Furthermore, postharvest restrictions may be placed on the fumigant in the future and organic growers do not use methyl bromide anyway. Cold treatments are long and difficult to apply. It would be very recommendable to have alternative disinfestation treatment options.

Irradiation quarantine treatments are currently being used to ship eight species of tropical fruits from Hawaii to the mainland U.S. and guavas and sweetpotatoes from Florida to other states. On May 26, 2000 the USDA-APHIS issued a proposed ruling in the Federal Register on importation of fruits and vegetables using irradiation against 12 quarantined pests. Trade agreements, such as the World Trade Organization, to which the U.S. and many of our trading partners subscribe, mandate that countries cannot discriminate against quarantine treatments if scientific evidence has found them to be safe and effective. After much study, irradiated food has been found to pose no safety risk, and irradiation is an effective quarantine treatment tolerated by more fruits than any other treatment, such as cold, heat, or methyl bromide fumigation. With these trade agreements in place, the U.S. and its trading partners cannot reasonably refuse irradiated produce.

Heated air treatments are used to disinfest papayas shipped from Hawaii to the mainland U.S. and citrus from Mexico. It is the quarantine treatment presently preferred by Japan. When coupled with low oxygen atmospheres, heat treatments can be performed in less time. Although apples are not highly tolerant of heat treatments, some heat treatment possibilities have been devised.

PROCEDURES:

Apple infestation: Organically-grown apples (red 'Delicious') from Washington state were subjected to oviposition by apple maggot in cages at the Weslaco facility and held at ambient temperatures until the insects develop to the most tolerant stages (late larvae for irradiation, eggs for heat).

Ionizing irradiation: Research completed during the first year suggested that under ambient conditions doses as low as 20 Gy might prevent adult emergence (Table 1). This research must be confirmed with larger numbers of insects treated. Apples with large larvae were irradiated using two cesium 137 gamma irradiators owned by USDA-APHIS in Mission, Texas. The apples were then held at ambient conditions until larvae emerged. Numbers of larvae, puparia, and adults were recorded. Because low oxygen conditions during irradiation are known to reduce the detrimental effects of irradiation on organisms and apples are stored under low oxygen, experiments were also conducted with infested apples in sealed tubes purged with nitrogen 3 times over a 18 hour period. The apples were held in the tubes for 20-21 hours before irradiation and removed about 1.5 hours after irradiation. (Any protection that low oxygen would have provided would be gone soon after the irradiation process was finished.)

Table 1. Pupation and adult emergence from ionizing radiation to large (3rd instar, the most radio-tolerant stage) apple maggot larvae in apples

Dose (Gy)	% adult emergence
0	92
10	9
15	1.1
20	0
25	0

Heat/CA: Weslaco has a Techni-Systems machine (same as Yakima and Wenatchee) that can do heat treatments with controlled atmospheres. Research last year demonstrated that eggs were the most tolerant apple maggot stage to heat/CA and estimated times that might be required to achieve 100% mortality (Table 2). Research this year concentrated on establishing the time spans necessary to provide total mortality of eggs at two treatment regimes: 1) 1.5% oxygen, 5% carbon dioxide at 44°C and 2) 1.5% oxygen, 5% carbon dioxide at 46°C. Failure of apple maggot eggs in apples to further develop into larvae was the measure of efficacy of the heat treatments.

Table 2. Estimated times to provide 100% mortality to eggs and early and late instar apple maggots

in apples treated at 44 or 46°C in an atmosphere of 1% oxygen, 15% carbon dioxide

Stage	Hours to 100% mortality at	
	44°C	46°C
Eggs	~4	~3
Early instar	~3	<3
Late instar	<3.5	<3

RESULTS:

Ionizing irradiation: After a total of about 1,700 large larvae were treated at 20 Gy, one adult fly emerged, so the dose was raised to 30 Gy. After about 3,500 larvae were treated at 30 Gy another adult emerged so the dose was raised to 40 Gy and no adults have emerged after several thousand have been treated. This research is continuing until a dose is confirmed with 10,000 larvae treated.

Adult emergence from infested apples irradiated with 20 Gy under low oxygen conditions was 5.3% compared with 0.06% for apples irradiated with 20 Gy in ambient atmosphere, demonstrating that irradiation in low oxygen storage does increase the survival rate of apple maggot considerably. Irradiations with 50 Gy in low oxygen atmospheres have not resulted in survivors after about 1,000 have been irradiated. These tests are continuing until a dose is confirmed with 10,000 larvae treated under low oxygen conditions. The results of the irradiation studies with apple maggot will be submitted for publication as soon as the large-scale testing is done late this year.

Heat/CA: The results of sequentially longer time periods for heat/CA treatments of apples infested with apple maggot eggs at 44 and 46°C are presented in Table 3. Times of 4.5 and 4 hours were necessary to achieve complete control at 44 and 46°C, respectively. Lisa Neven (ARS-Yakima) and Steve Drake (ARS-Wenatchee), are studying apple quality after heat/CA treatments and feel that apples will tolerate the treatment necessary to kill apple maggot and other pests.

Table 3. Survival of apple maggot eggs in apples treated in atmospheres containing 1.5% oxygen, 5% carbon dioxide at 44 and 46°C

Temperature, Time (hours)	% survival
44°C, 3.5 h	8.5
4 h	0.6
4.5 h	0
46°C, 3 h	8.7
3.5 h	0.2
4 h	0